Using the GNU Compiler Collection

For GCC version 16.0.0 (pre-release)

(GCC)

Richard M. Stallman and the GCC Developer Community

Published by:

GNU Press
a division of the
Free Software Foundation
51 Franklin Street, Fifth Floor
Boston, MA 02110-1301 USA

Website: http://www.gnupress.org
General: press@gnu.org
Orders: sales@gnu.org
Tel 617-542-5942
Fax 617-542-2652

Last printed October 2003 for GCC 3.3.1.
Printed copies are available for $45 each.

This file documents the use of the GNU compilers.

Short Contents

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1 Programming Languages Supported by GCC

GCC stands for "GNU Compiler Collection". GCC is an integrated distribution of compilers for several major programming languages. These languages currently include C, C++, Objective-C, Objective-C++, Fortran, Ada, D, and Go.

The abbreviation *GCC* has multiple meanings in common use. The current official meaning is "GNU Compiler Collection", which refers generically to the complete suite of tools. The name historically stood for "GNU C Compiler", and this usage is still common when the emphasis is on compiling C programs. Finally, the name is also used when speaking of the *language-independent* component of GCC: code shared among the compilers for all supported languages.

The language-independent component of GCC includes the majority of the optimizers, as well as the "back ends" that generate machine code for various processors.

The part of a compiler that is specific to a particular language is called the "front end". In addition to the front ends that are integrated components of GCC, there are several other front ends that are maintained separately. These support languages such as Mercury. To use these, they must be built together with GCC proper.

Most of the compilers for languages other than C have their own names. The C++ compiler is G++, the COBOL compiler is gcobol, the Ada compiler is GNAT, and so on. When we talk about compiling one of those languages, we might refer to that compiler by its own name, or as GCC. Either is correct.

Historically, compilers for many languages, including C++ and Fortran, have been implemented as "preprocessors" which emit another high level language such as C. None of the compilers included in GCC are implemented this way; they all generate machine code directly. This sort of preprocessor should not be confused with the *C preprocessor*, which is an integral feature of the C, C++, Objective-C and Objective-C++ languages.

2 Language Standards Supported by GCC

For each language compiled by GCC for which there is a standard, GCC attempts to follow one or more versions of that standard, possibly with some exceptions, and possibly with some extensions.

2.1 C Language

The original ANSI C standard (X3.159-1989) was ratified in 1989 and published in 1990. This standard was ratified as an ISO standard (ISO/IEC 9899:1990) later in 1990. There were no technical differences between these publications, although the sections of the ANSI standard were renumbered and became clauses in the ISO standard. The ANSI standard, but not the ISO standard, also came with a Rationale document. This standard, in both its forms, is commonly known as *C89*, or occasionally as *C90*, from the dates of ratification. To select this standard in GCC, use one of the options `-ansi`, `-std=c90` or `-std=iso9899:1990`; to obtain all the diagnostics required by the standard, you should also specify `-pedantic` (or `-pedantic-errors` if you want them to be errors rather than warnings). See Section 3.4 [Options Controlling C Dialect], page 45.

Errors in the 1990 ISO C standard were corrected in two Technical Corrigenda published in 1994 and 1996. GCC does not support the uncorrected version.

An amendment to the 1990 standard was published in 1995. This amendment added digraphs and `__STDC_VERSION__` to the language, but otherwise concerned the library. This amendment is commonly known as *AMD1*; the amended standard is sometimes known as *C94* or *C95*. To select this standard in GCC, use the option `-std=iso9899:199409` (with, as for other standard versions, `-pedantic` to receive all required diagnostics).

A new edition of the ISO C standard was published in 1999 as ISO/IEC 9899:1999, and is commonly known as *C99*. (While in development, drafts of this standard version were referred to as *C9X*.) GCC has substantially complete support for this standard version; see `https://gcc.gnu.org/projects/c-status.html` for details. To select this standard, use `-std=c99` or `-std=iso9899:1999`.

Errors in the 1999 ISO C standard were corrected in three Technical Corrigenda published in 2001, 2004 and 2007. GCC does not support the uncorrected version.

A fourth version of the C standard, known as *C11*, was published in 2011 as ISO/IEC 9899:2011. (While in development, drafts of this standard version were referred to as *C1X*.) GCC has substantially complete support for this standard, enabled with `-std=c11` or `-std=iso9899:2011`. A version with corrections integrated was prepared in 2017 and published in 2018 as ISO/IEC 9899:2018; it is known as *C17* and is supported with `-std=c17` or `-std=iso9899:2017`; the corrections are also applied with `-std=c11`, and the only difference between the options is the value of `__STDC_VERSION__`.

A fifth version of the C standard, known as *C23*, was published in 2024 as ISO/IEC 9899:2024. (While in development, drafts of this standard version were referred to as *C2X*.) Support for this is enabled with `-std=c23` or `-std=iso9899:2024`.

A further version of the C standard, known as *C2Y*, is under development; experimental and incomplete support for this is enabled with `-std=c2y`.

By default, GCC provides some extensions to the C language that, on rare occasions conflict with the C standard. See Chapter 6 [Extensions to the C Language Family], page 603.

Some features that are part of the C99 standard are accepted as extensions in C90 mode, and some features that are part of the C11 standard are accepted as extensions in C90 and C99 modes. Use of the `-std` options listed above disables these extensions where they conflict with the C standard version selected. You may also select an extended version of the C language explicitly with `-std=gnu90` (for C90 with GNU extensions), `-std=gnu99` (for C99 with GNU extensions), `-std=gnu11` (for C11 with GNU extensions), `-std=gnu17` (for C17 with GNU extensions) or `-std=gnu23` (for C23 with GNU extensions).

The default, if no C language dialect options are given, is `-std=gnu23`.

The ISO C standard defines (in clause 4) two classes of conforming implementation. A *conforming hosted implementation* supports the whole standard including all the library facilities; a *conforming freestanding implementation* is only required to provide certain library facilities: those in `<float.h>`, `<limits.h>`, `<stdarg.h>`, and `<stddef.h>`; since AMD1, also those in `<iso646.h>`; since C99, also those in `<stdbool.h>` and `<stdint.h>`; and since C11, also those in `<stdalign.h>` and `<stdnoreturn.h>`. In addition, complex types, added in C99, are not required for freestanding implementations. Since C23, freestanding implementations are required to support a larger range of library facilities, including some functions from other headers.

The standard also defines two environments for programs, a *freestanding environment*, required of all implementations and which may not have library facilities beyond those required of freestanding implementations, where the handling of program startup and termination are implementation-defined; and a *hosted environment*, which is not required, in which all the library facilities are provided and startup is through a function `int main (void)` or `int main (int, char *[])`. An OS kernel is an example of a program running in a freestanding environment; a program using the facilities of an operating system is an example of a program running in a hosted environment.

GCC aims towards being usable as the compiler for a conforming freestanding or hosted implementation. By default, it acts as the compiler for a hosted implementation, defining `__STDC_HOSTED__` as `1` and presuming that when the names of ISO C functions are used, they have the semantics defined in the standard. To make it act as the compiler for a freestanding environment, use the option `-ffreestanding`; it then defines `__STDC_HOSTED__` to `0` and does not make assumptions about the meanings of function names from the standard library, with exceptions noted below. To build an OS kernel, you may well still need to make your own arrangements for linking and startup. See Section 3.4 [Options Controlling C Dialect], page 45.

GCC generally provides library facilities in headers that do not declare functions with external linkage (which includes the headers required by C11 and before to be provided by freestanding implementations), but not those included in other headers. Additionally, GCC provides `<stdatomic.h>`, even though it declares some functions with external linkage (which are provided in `libatomic`). On a few platforms, some of the headers not declaring functions with external linkage are instead obtained from the OS's C library, which may mean that they lack support for features from more recent versions of the C standard that are supported in GCC's own versions of those headers. On some platforms, GCC provides `<tgmath.h>` (but this implementation does not support interfaces added in C23).

To use the facilities of a hosted environment, and some of the facilities required in a freestanding environment by C23, you need to find them elsewhere (for example, in the GNU C library). See Section 15.5 [Standard Libraries], page 1134.

Most of the compiler support routines used by GCC are present in `libgcc`, but there are a few exceptions. GCC requires the freestanding environment provide `memcpy`, `memmove`, `memset` and `memcmp`. Contrary to the standards covering `memcpy` GCC expects the case of an exact overlap of source and destination to work and not invoke undefined behavior. Finally, if `__builtin_trap` is used, and the target does not implement the `trap` pattern, then GCC emits a call to `abort`.

For references to Technical Corrigenda, Rationale documents and information concerning the history of C that is available online, see `https://gcc.gnu.org/readings.html`

2.2 C++ Language

GCC supports the original ISO C++ standard published in 1998, and the 2011, 2014, 2017 and mostly 2020 and 2024 revisions.

The original ISO C++ standard was published as the ISO standard (ISO/IEC 14882:1998) and amended by a Technical Corrigenda published in 2003 (ISO/IEC 14882:2003). These standards are referred to as C++98 and C++03, respectively. GCC implements the majority of C++98 (`export` is a notable exception) and most of the changes in C++03. To select this standard in GCC, use one of the options `-ansi`, `-std=c++98`, or `-std=c++03`; to obtain all the diagnostics required by the standard, you should also specify `-pedantic` (or `-pedantic-errors` if you want them to be errors rather than warnings).

A revised ISO C++ standard was published in 2011 as ISO/IEC 14882:2011, and is referred to as C++11; before its publication it was commonly referred to as C++0x. C++11 contains several changes to the C++ language, all of which have been implemented in GCC. For details see `https://gcc.gnu.org/projects/cxx-status.html#cxx11`. To select this standard in GCC, use the option `-std=c++11`.

Another revised ISO C++ standard was published in 2014 as ISO/IEC 14882:2014, and is referred to as C++14; before its publication it was sometimes referred to as C++1y. C++14 contains several further changes to the C++ language, all of which have been implemented in GCC. For details see `https://gcc.gnu.org/projects/cxx-status.html#cxx14`. To select this standard in GCC, use the option `-std=c++14`.

The C++ language was further revised in 2017 and ISO/IEC 14882:2017 was published. This is referred to as C++17, and before publication was often referred to as C++1z. GCC supports all the changes in that specification. For further details see `https://gcc.gnu.org/projects/cxx-status.html#cxx17`. Use the option `-std=c++17` to select this variant of C++.

Another revised ISO C++ standard was published in 2020 as ISO/IEC 14882:2020, and is referred to as C++20; before its publication it was sometimes referred to as C++2a. GCC supports most of the changes in the new specification. For further details see `https://gcc.gnu.org/projects/cxx-status.html#cxx20`. To select this standard in GCC, use the option `-std=c++20`.

Yet another revised ISO C++ standard was published in 2024 as ISO/IEC 14882:2024, and is referred to as C++23; before its publication it was sometimes referred to as C++2b. GCC supports most of the changes in the new specification. For further details see `https://gcc.gnu.org/projects/cxx-status.html#cxx23`. To select this standard in GCC, use the option `-std=c++23`.

More information about the C++ standards is available on the ISO C++ committee's web site at `https://www.open-std.org/jtc1/sc22/wg21/`.

To obtain all the diagnostics required by any of the standard versions described above you should specify `-pedantic` or `-pedantic-errors`, otherwise GCC will allow some non-ISO C++ features as extensions. See Section 3.9 [Warning Options], page 100.

By default, GCC also provides some additional extensions to the C++ language that on rare occasions conflict with the C++ standard. See Section 3.5 [C++ Dialect Options], page 52. Use of the `-std` options listed above disables these extensions where they they conflict with the C++ standard version selected. You may also select an extended version of the C++ language explicitly with `-std=gnu++98` (for C++98 with GNU extensions), or `-std=gnu++11` (for C++11 with GNU extensions), or `-std=gnu++14` (for C++14 with GNU extensions), or `-std=gnu++17` (for C++17 with GNU extensions), or `-std=gnu++20` (for C++20 with GNU extensions), or `-std=gnu++23` (for C++23 with GNU extensions).

The default, if no C++ language dialect options are given, is `-std=gnu++20`.

2.3 Objective-C and Objective-C++ Languages

GCC supports "traditional" Objective-C (also known as "Objective-C 1.0") and contains support for the Objective-C exception and synchronization syntax. It has also support for a number of "Objective-C 2.0" language extensions, including properties, fast enumeration (only for Objective-C), method attributes and the @optional and @required keywords in protocols. GCC supports Objective-C++ and features available in Objective-C are also available in Objective-C++.

GCC by default uses the GNU Objective-C runtime library, which is part of GCC and is not the same as the Apple/NeXT Objective-C runtime library used on Apple systems. There are a number of differences documented in this manual. The options `-fgnu-runtime` and `-fnext-runtime` allow you to switch between producing output that works with the GNU Objective-C runtime library and output that works with the Apple/NeXT Objective-C runtime library.

There is no formal written standard for Objective-C or Objective-C++. The authoritative manual on traditional Objective-C (1.0) is "Object-Oriented Programming and the Objective-C Language" (`https://www.gnustep.org/resources/documentation/ObjectivCBook.pdf`).

The Objective-C exception and synchronization syntax (that is, the keywords `@try`, `@throw`, `@catch`, `@finally` and `@synchronized`) is supported by GCC and is enabled with the option `-fobjc-exceptions`. The syntax is briefly documented in this manual and in the Objective-C 2.0 manuals from Apple.

The Objective-C 2.0 language extensions and features are automatically enabled; they include properties (via the `@property`, `@synthesize` and `@dynamic keywords`), fast enumeration (not available in Objective-C++), attributes for methods (such as `deprecated`, `noreturn`, `sentinel`, `format`), the `unused` attribute for method arguments, the `@package` keyword for instance variables and the `@optional` and `@required` keywords in protocols. You can disable all these Objective-C 2.0 language extensions with the option `-fobjc-std=objc1`, which causes the compiler to recognize the same Objective-C language syntax recognized by GCC 4.0, and to produce an error if one of the new features is used.

GCC has currently no support for non-fragile instance variables.

The authoritative manual on Objective-C 2.0 is available from Apple:

- `https://developer.apple.com/library/archive/documentation/Cocoa/Conceptual/ProgrammingWithObjectiveC/Introduction/Introduction.html`

For more information concerning the history of Objective-C that is available online, see `https://gcc.gnu.org/readings.html`

2.4 COBOL Language

As of the GCC 15 release, GCC supports the ISO COBOL language standard (ISO/IEC 1989:2023). It includes some support for compatibility with other COBOL compilers via the `-dialect` option.

2.5 Go Language

As of the GCC 4.7.1 release, GCC supports the Go 1 language standard, described at `https://go.dev/doc/go1`.

2.6 D language

GCC supports the D 2.0 programming language. The D language itself is currently defined by its reference implementation and supporting language specification, described at `https://dlang.org/spec/spec.html`.

2.7 Modula-2 language

GCC supports the Modula-2 language and is compliant with the PIM2, PIM3, PIM4 and ISO dialects. Also implemented are a complete set of free ISO libraries. It also contains a collection of PIM libraries and some Logitech compatible libraries.

For more information on Modula-2 see `https://gcc.gnu.org/readings.html`. The online manual is available at `https://gcc.gnu.org/onlinedocs/gm2/index.html`.

2.8 References for Other Languages

See Section "About This Guide" in *GNAT Reference Manual*, for information on standard conformance and compatibility of the Ada compiler.

See Section "Standards" in *The GNU Fortran Compiler*, for details of standards supported by GNU Fortran.

3 GCC Command Options

When you invoke GCC, it normally does preprocessing, compilation, assembly and linking. The "overall options" allow you to stop this process at an intermediate stage. For example, the `-c` option says not to run the linker. Then the output consists of object files output by the assembler. See Section 3.2 [Options Controlling the Kind of Output], page 34.

Other options are passed on to one or more stages of processing. Some options control the preprocessor and others the compiler itself. Yet other options control the assembler and linker; most of these are not documented here, since you rarely need to use any of them.

Most of the command-line options that you can use with GCC are useful for C programs; when an option is only useful with another language (usually C++), the explanation says so explicitly. If the description for a particular option does not mention a source language, you can use that option with all supported languages.

The usual way to run GCC is to run the executable called `gcc`, or *machine*-`gcc` when cross-compiling, or *machine*-`gcc`-*version* to run a specific version of GCC. When you compile C++ programs, you should invoke GCC as `g++` instead. See Section 3.3 [Compiling C++ Programs], page 45, for information about the differences in behavior between `gcc` and `g++` when compiling C++ programs.

The `gcc` program accepts options and file names as operands. Many options have multi-letter names; therefore multiple single-letter options may *not* be grouped: `-dv` is very different from '`-d -v`'.

You can mix options and other arguments. For the most part, the order you use doesn't matter. Order does matter when you use several options of the same kind; for example, if you specify `-L` more than once, the directories are searched in the order specified. Also, the placement of the `-l` option is significant.

Many options have long names starting with '`-f`' or with '`-W`'—for example, `-fmove-loop-invariants`, `-Wformat` and so on. Most of these have both positive and negative forms; the negative form of `-ffoo` is `-fno-foo`. This manual documents only one of these two forms, whichever one is not the default.

Some options take one or more arguments typically separated either by a space or by the equals sign ('`=`') from the option name. Unless documented otherwise, an argument can be either numeric or a string. Numeric arguments must typically be small unsigned decimal or hexadecimal integers. Hexadecimal arguments must begin with the '`0x`' prefix. Arguments to options that specify a size threshold of some sort may be arbitrarily large decimal or hexadecimal integers followed by a byte size suffix designating a multiple of bytes such as `kB` and `KiB` for kilobyte and kibibyte, respectively, `MB` and `MiB` for megabyte and mebibyte, `GB` and `GiB` for gigabyte and gigibyte, and so on. Such arguments are designated by *byte-size* in the following text. Refer to the NIST, IEC, and other relevant national and international standards for the full listing and explanation of the binary and decimal byte size prefixes.

See Section A.1 [Option Index], page 1193, for an index to GCC's options.

3.1 Option Summary

Here is a summary of all the options, grouped by type. Explanations are in the following sections.

Overall Options

See Section 3.2 [Options Controlling the Kind of Output], page 34.

```
-c  -S  -E  -o file
-dumpbase dumpbase  -dumpbase-ext auxdropsuf
-dumpdir dumppfx  -x language
-v  -###  --help[=class[,...]]  --target-help  --version
-pass-exit-codes  -pipe  -specs=file  -wrapper
@file  -ffile-prefix-map=old=new  -fcanon-prefix-map
-fplugin=file  -fplugin-arg-name=arg
-fdump-ada-spec[-slim]  -fada-spec-parent=unit
-fdump-go-spec=file
--assemble  --compile  --dumpbase dumpbase
--dumpbase-ext auxdropsuf  --dumpdir dumppfx
--language=language  --output=file  --pass-exit-codes
--pipe  --preprocess  --specs=file  --verbose
```

C Language Options

See Section 3.4 [Options Controlling C Dialect], page 45.

```
-ansi  -std=standard  -aux-info filename
-fno-asm
-fno-builtin  -fno-builtin-function  -fcond-mismatch
-ffreestanding  -fgimple  -fgnu-tm  -fgnu89-inline  -fhosted
-flax-vector-conversions  -fms-extensions
-fpermitted-flt-eval-methods=standard
-fplan9-extensions  -fsigned-bitfields  -funsigned-bitfields
-fsigned-char  -funsigned-char  -fstrict-flex-arrays[=n]
-fsso-struct=endianness  --ansi
```

C++ Language Options

See Section 3.5 [Options Controlling C++ Dialect], page 52.

```
--compile-std-module
-fabi-compat-version=n -fabi-version=n
-fno-access-control  -faligned-new=[n]
-fno-assume-sane-operators-new-delete
-fchar8_t  -fcheck-new
-fconcepts  -fconcepts-diagnostics-depth=n
-fconstexpr-depth=n  -fconstexpr-cache-depth=n
-fconstexpr-loop-limit=n  -fconstexpr-ops-limit=n
-fcontracts  -fcontract-assumption-mode=[on|off]
-fcontract-build-level=[off|default|audit]
-fcontract-continuation-mode=[on|off]
-fcontract-mode=[on|off]
-fcontract-role=name:default,audit,axiom
-fcontract-semantic=[default|audit|axiom]:semantic
-fcontract-strict-declarations=[on|off]
-fcoroutines  -fdiagnostics-all-candidates
-fno-elide-constructors
-fno-enforce-eh-specs
-fext-numeric-literals
-fno-gnu-keywords
-fno-immediate-escalation
-fno-implement-inlines
-fimplicit-constexpr
-fno-implicit-inline-templates
-fno-implicit-templates
-fmodule-header[=kind]
-fmodule-implicit-inline
-fno-module-lazy
```

```
-fmodule-mapper=specification
-fmodule-only
-fmodules
-fms-extensions
-fnew-inheriting-ctors
-fnew-ttp-matching
-fno-nonansi-builtins  -fnothrow-opt  -fno-operator-names
-fno-optional-diags
-fno-pretty-templates  -frange-for-ext-temps
-fno-rtti  -fsized-deallocation
-fstrict-enums  -fstrong-eval-order[=kind]
-ftemplate-backtrace-limit=n
-ftemplate-depth=n
-fno-threadsafe-statics  -fuse-cxa-atexit  -fno-use-cxa-get-exception-ptr
-fno-weak  -nostdinc++
-fvisibility-inlines-hidden
-fvisibility-ms-compat
-flang-info-include-translate[=header]
-flang-info-include-translate-not
-flang-info-module-cmi[=module]
-stdlib=libstdc++,libc++
-Wabbreviated-auto-in-template-arg
-Wabi-tag  -Waligned-new[=kind]
-Wcatch-value  -Wcatch-value=n
-Wno-class-conversion  -Wclass-memaccess
-Wcomma-subscript  -Wconditionally-supported
-Wno-conversion-null  -Wctad-maybe-unsupported
-Wctor-dtor-privacy  -Wdangling-reference
-Wno-defaulted-function-deleted
-Wno-delete-incomplete
-Wdelete-non-virtual-dtor  -Wno-deprecated-array-compare
-Wdeprecated-copy  -Wdeprecated-copy-dtor
-Wno-deprecated-enum-enum-conversion  -Wno-deprecated-enum-float-conversion
-Wno-deprecated-literal-operator  -Wdeprecated-variadic-comma-omission
-Weffc++  -Wno-elaborated-enum-base
-Wno-exceptions  -Wno-expose-global-module-tu-local  -Wno-external-tu-local
-Wextra-semi  -Wno-global-module  -Wno-inaccessible-base
-Wno-inherited-variadic-ctor  -Wno-init-list-lifetime
-Winvalid-constexpr  -Winvalid-imported-macros
-Wno-invalid-offsetof  -Wno-literal-suffix
-Wmismatched-new-delete  -Wmismatched-tags
-Wmultiple-inheritance  -Wnamespaces  -Wnarrowing
-Wnoexcept  -Wnoexcept-type  -Wnon-virtual-dtor
-Wpessimizing-move  -Wno-placement-new  -Wplacement-new=n
-Wrange-loop-construct  -Wredundant-move  -Wredundant-tags
-Wreorder  -Wregister  -Wno-sfinae-incomplete
-Wstrict-null-sentinel  -Wno-subobject-linkage  -Wtemplates
-Wno-non-c-typedef-for-linkage  -Wno-non-template-friend  -Wold-style-cast
-Woverloaded-virtual  -Wno-pmf-conversions  -Wself-move  -Wsign-promo
-Wsized-deallocation  -Wsuggest-final-methods
-Wsuggest-final-types  -Wsuggest-override  -Wno-template-body
-Wno-template-id-cdtor  -Wtemplate-names-tu-local
-Wno-terminate  -Wno-vexing-parse  -Wvirtual-inheritance
-Wno-virtual-move-assign  -Wvolatile
```

Objective-C and Objective-C++ Language Options

See Section 3.6 [Options Controlling Objective-C and Objective-C++ Dialects], page 82.

```
-fconstant-string-class=class-name
-fgnu-runtime  -fnext-runtime
-fno-nil-receivers
-fobjc-abi-version=n
-fobjc-call-cxx-cdtors
-fobjc-direct-dispatch
-fobjc-exceptions
-fobjc-gc
-fobjc-nilcheck
-fobjc-std=objc1
-fno-local-ivars
-fivar-visibility=[public|protected|private|package]
-freplace-objc-classes
-fzero-link
-gen-decls
-Wassign-intercept  -Wno-property-assign-default
-Wno-protocol -Wobjc-root-class -Wselector
-Wstrict-selector-match
-Wundeclared-selector
```

OpenMP and OpenACC Options

See Section 3.7 [Options Controlling OpenMP and OpenACC], page 86.

```
-foffload=arg  -foffload-options=arg
-fopenacc  -fopenacc-dim=geom
-fopenmp  -fopenmp-simd  -fopenmp-target-simd-clone[=device-type]
```

Diagnostic Message Formatting Options

See Section 3.8 [Options to Control Diagnostic Messages Formatting], page 88.

```
-fmessage-length=n
-fdiagnostics-plain-output
-fdiagnostics-show-location=[once|every-line]
-fdiagnostics-color=[auto|never|always]
-fdiagnostics-urls=[auto|never|always]
-fdiagnostics-format=[text|sarif-stderr|sarif-file]
-fdiagnostics-add-output=DIAGNOSTICS-OUTPUT-SPEC
-fdiagnostics-set-output=DIAGNOSTICS-OUTPUT-SPEC
-fno-diagnostics-json-formatting
-fno-diagnostics-show-option  -fno-diagnostics-show-caret
-fno-diagnostics-show-event-links
-fno-diagnostics-show-labels  -fno-diagnostics-show-line-numbers
-fno-diagnostics-show-cwe
-fno-diagnostics-show-rules
-fno-diagnostics-show-highlight-colors
-fno-diagnostics-show-nesting
-fno-diagnostics-show-nesting-locations
-fdiagnostics-show-nesting-levels
-fdiagnostics-minimum-margin-width=width
-fdiagnostics-parseable-fixits  -fdiagnostics-generate-patch
-fdiagnostics-show-template-tree  -fno-elide-type
-fdiagnostics-path-format=[none|separate-events|inline-events]
-fdiagnostics-show-path-depths
-fno-show-column
-fdiagnostics-column-unit=[display|byte]
-fdiagnostics-column-origin=origin
-fdiagnostics-escape-format=[unicode|bytes]
-fdiagnostics-text-art-charset=[none|ascii|unicode|emoji]
-fdiagnostics-show-context[=depth]
```

Warning Options

See Section 3.9 [Options to Request or Suppress Warnings], page 100.

```
-fsyntax-only  -fmax-errors=n  -Wpedantic
-pedantic-errors -fpermissive
-w  -Wextra  -Wall  -Wabi=n
-Waddress  -Wno-address-of-packed-member  -Waggregate-return
-Walloc-size  -Walloc-size-larger-than=byte-size  -Walloc-zero
-Walloca  -Walloca-larger-than=byte-size  -Wauto-profile
-Wno-aggressive-loop-optimizations
-Warith-conversion
-Warray-bounds  -Warray-bounds=n  -Warray-compare
-Warray-parameter  -Warray-parameter=n
-Wno-attributes  -Wattribute-alias=n -Wno-attribute-alias
-Wno-attribute-warning
-Wbidi-chars=[none|unpaired|any|ucn]
-Wbool-compare  -Wbool-operation
-Wno-builtin-declaration-mismatch
-Wno-builtin-macro-redefined  -Wc90-c99-compat  -Wc99-c11-compat
-Wc11-c23-compat  -Wc23-c2y-compat
-Wc++-compat  -Wc++11-compat  -Wc++14-compat  -Wc++17-compat
-Wc++20-compat  -Wc++26-compat
-Wno-c++11-extensions  -Wno-c++14-extensions -Wno-c++17-extensions
-Wno-c++20-extensions  -Wno-c++23-extensions
-Wcalloc-transposed-args  -Wcannot-profile
-Wcast-align  -Wcast-align=strict  -Wcast-function-type  -Wcast-qual
-Wchar-subscripts
-Wclobbered  -Wcomment
-Wcompare-distinct-pointer-types
-Wno-complain-wrong-lang
-Wconversion  -Wno-coverage-mismatch  -Wno-cpp
-Wdangling-else  -Wdangling-pointer  -Wdangling-pointer=n
-Wdate-time
-Wno-deprecated  -Wno-deprecated-declarations  -Wno-designated-init
-Wdisabled-optimization
-Wno-discarded-array-qualifiers  -Wno-discarded-qualifiers
-Wno-div-by-zero  -Wdouble-promotion
-Wduplicated-branches  -Wduplicated-cond
-Wempty-body  -Wno-endif-labels  -Wenum-compare  -Wenum-conversion
-Wenum-int-mismatch
-Werror  -Werror=*  -Wexpansion-to-defined  -Wfatal-errors
-Wflex-array-member-not-at-end
-Wfloat-conversion  -Wfloat-equal  -Wformat  -Wformat=2
-Wno-format-contains-nul  -Wno-format-diag  -Wno-format-extra-args
-Wformat-nonliteral  -Wformat-overflow=n
-Wformat-security  -Wformat-signedness  -Wformat-truncation=n
-Wformat-y2k  -Wframe-address
-Wframe-larger-than=byte-size  -Wno-free-nonheap-object
-Wheader-guard  -Wno-if-not-aligned  -Wno-ignored-attributes
-Wignored-qualifiers  -Wno-incompatible-pointer-types  -Whardened
-Wimplicit  -Wimplicit-fallthrough  -Wimplicit-fallthrough=n
-Wno-implicit-function-declaration  -Wno-implicit-int
-Winfinite-recursion
-Winit-self  -Winline  -Wno-int-conversion  -Wint-in-bool-context
-Wno-int-to-pointer-cast  -Wno-invalid-memory-model
-Winvalid-pch  -Winvalid-utf8  -Wno-unicode  -Wjump-misses-init
-Wkeyword-macro
-Wlarger-than=byte-size  -Wleading-whitespace=kind
-Wlogical-not-parentheses  -Wlogical-op
```

```
-Wlong-long  -Wno-lto-type-mismatch -Wmain  -Wmaybe-uninitialized
-Wmemset-elt-size  -Wmemset-transposed-args
-Wmisleading-indentation  -Wmissing-attributes  -Wmissing-braces
-Wmissing-field-initializers  -Wmissing-format-attribute
-Wmissing-include-dirs  -Wmissing-noreturn  -Wmusttail-local-addr
-Wmaybe-musttail-local-addr  -Wno-missing-profile
-Wno-multichar  -Wmultistatement-macros  -Wnonnull  -Wnonnull-compare
-Wnormalized=[none|id|nfc|nfkc]
-Wnull-dereference  -Wno-odr
-Wopenacc-parallelism
-Wopenmp -Wopenmp-simd
-Wno-overflow  -Woverlength-strings  -Wno-override-init-side-effects
-Wpacked  -Wno-packed-bitfield-compat  -Wpacked-not-aligned  -Wpadded
-Wparentheses  -Wno-pedantic-ms-format
-Wpointer-arith  -Wno-pointer-compare  -Wno-pointer-to-int-cast
-Wno-pragmas  -Wno-pragma-once-outside-header  -Wno-prio-ctor-dtor
-Wno-psabi
-Wredundant-decls  -Wrestrict
-Wno-return-local-addr  -Wreturn-type
-Wno-scalar-storage-order  -Wsequence-point
-Wshadow  -Wshadow=global  -Wshadow=local  -Wshadow=compatible-local
-Wno-shadow-ivar
-Wno-shift-count-negative  -Wno-shift-count-overflow  -Wshift-negative-value
-Wno-shift-overflow  -Wshift-overflow=n
-Wsign-compare  -Wsign-conversion
-Wno-sizeof-array-argument
-Wsizeof-array-div
-Wsizeof-pointer-div  -Wsizeof-pointer-memaccess
-Wstack-protector  -Wstack-usage=byte-size  -Wstrict-aliasing
-Wstrict-aliasing=n  -Wstrict-overflow  -Wstrict-overflow=n
-Wstring-compare
-Wno-stringop-overflow -Wno-stringop-overread
-Wno-stringop-truncation  -Wstrict-flex-arrays
-Wsuggest-attribute=attribute-name
-Wswitch  -Wno-switch-bool  -Wswitch-default  -Wswitch-enum
-Wno-switch-outside-range  -Wno-switch-unreachable  -Wsync-nand
-Wsystem-headers  -Wtautological-compare  -Wtrailing-whitespace
-Wtrailing-whitespace=kind  -Wtrampolines  -Wtrigraphs
-Wtrivial-auto-var-init  -Wno-tsan  -Wtype-limits  -Wundef
-Wuninitialized  -Wunknown-pragmas
-Wunsuffixed-float-constants
-Wunterminated-string-initialization
-Wunused
-Wunused-but-set-parameter  -Wunused-but-set-parameter=n
-Wunused-but-set-variable  -Wunused-but-set-variable=n
-Wunused-const-variable  -Wunused-const-variable=n
-Wunused-function  -Wunused-label  -Wunused-local-typedefs
-Wunused-macros
-Wunused-parameter  -Wno-unused-result
-Wunused-value  -Wunused-variable
-Wuse-after-free  -Wuse-after-free=n  -Wuseless-cast
-Wno-varargs  -Wvariadic-macros
-Wvector-operation-performance
-Wvla  -Wvla-larger-than=byte-size  -Wno-vla-larger-than
-Wvolatile-register-var  -Wwrite-strings
-Wno-xor-used-as-pow
-Wzero-as-null-pointer-constant
-Wzero-length-bounds
```

```
--all-warnings  --extra-warnings  --no-warnings
--pedantic  --pedantic-errors
```

Static Analyzer Options

```
-fanalyzer
-fanalyzer-call-summaries
-fanalyzer-checker=name
-fno-analyzer-feasibility
-fanalyzer-fine-grained
-fanalyzer-show-events-in-system-headers
-fno-analyzer-state-merge
-fno-analyzer-state-purge
-fno-analyzer-suppress-followups
-fanalyzer-transitivity
-fno-analyzer-undo-inlining
-fanalyzer-verbose-edges
-fanalyzer-verbose-state-changes
-fanalyzer-verbosity=level
-fdump-analyzer
-fdump-analyzer-callgraph
-fdump-analyzer-exploded-graph
-fdump-analyzer-exploded-nodes
-fdump-analyzer-exploded-nodes-2
-fdump-analyzer-exploded-nodes-3
-fdump-analyzer-exploded-paths
-fdump-analyzer-feasibility
-fdump-analyzer-infinite-loop
-fdump-analyzer-json
-fdump-analyzer-state-purge
-fdump-analyzer-stderr
-fdump-analyzer-supergraph
-fdump-analyzer-untracked
-Wno-analyzer-double-fclose
-Wno-analyzer-double-free
-Wno-analyzer-exposure-through-output-file
-Wno-analyzer-exposure-through-uninit-copy
-Wno-analyzer-fd-access-mode-mismatch
-Wno-analyzer-fd-double-close
-Wno-analyzer-fd-leak
-Wno-analyzer-fd-phase-mismatch
-Wno-analyzer-fd-type-mismatch
-Wno-analyzer-fd-use-after-close
-Wno-analyzer-fd-use-without-check
-Wno-analyzer-file-leak
-Wno-analyzer-free-of-non-heap
-Wno-analyzer-imprecise-fp-arithmetic
-Wno-analyzer-infinite-loop
-Wno-analyzer-infinite-recursion
-Wno-analyzer-jump-through-null
-Wno-analyzer-malloc-leak
-Wno-analyzer-mismatching-deallocation
-Wno-analyzer-null-argument
-Wno-analyzer-null-dereference
-Wno-analyzer-out-of-bounds
-Wno-analyzer-overlapping-buffers
-Wno-analyzer-possible-null-argument
-Wno-analyzer-possible-null-dereference
-Wno-analyzer-putenv-of-auto-var
```

```
-Wno-analyzer-shift-count-negative
-Wno-analyzer-shift-count-overflow
-Wno-analyzer-stale-setjmp-buffer
-Wno-analyzer-tainted-allocation-size
-Wno-analyzer-tainted-assertion
-Wno-analyzer-tainted-array-index
-Wno-analyzer-tainted-divisor
-Wno-analyzer-tainted-offset
-Wno-analyzer-tainted-size
-Wno-analyzer-throw-of-unexpected-type
-Wanalyzer-symbol-too-complex
-Wanalyzer-too-complex
-Wno-analyzer-undefined-behavior-ptrdiff
-Wno-analyzer-undefined-behavior-strtok
-Wno-analyzer-unsafe-call-within-signal-handler
-Wno-analyzer-use-after-free
-Wno-analyzer-use-of-pointer-in-stale-stack-frame
-Wno-analyzer-use-of-uninitialized-value
-Wno-analyzer-va-arg-type-mismatch
-Wno-analyzer-va-list-exhausted
-Wno-analyzer-va-list-leak
-Wno-analyzer-va-list-use-after-va-end
-Wno-analyzer-write-to-const
-Wno-analyzer-write-to-string-literal
```

C and Objective-C-only Warning Options

```
-Wbad-function-cast -Wdeprecated-non-prototype -Wfree-labels
-Wmissing-declarations -Wmissing-parameter-name -Wmissing-parameter-type
-Wdeclaration-missing-parameter-type -Wmissing-prototypes
-Wmissing-variable-declarations
-Wmultiple-parameter-fwd-decl-lists
-Wnested-externs -Wold-style-declaration
-Wold-style-definition -Wstrict-prototypes -Wtraditional
-Wtraditional-conversion -Wdeclaration-after-statement -Wpointer-sign
```

Debugging Options

See Section 3.11 [Options for Debugging Your Program], page 187.

```
-g  -glevel  -gdwarf  -gdwarf-version
-gbtf -gctf  -gctflevel
-gprune-btf -gno-prune-btf
-ggdb  -grecord-gcc-switches  -gno-record-gcc-switches
-gstrict-dwarf  -gno-strict-dwarf
-gas-loc-support  -gno-as-loc-support
-gas-locview-support  -gno-as-locview-support
-gcodeview
-gcolumn-info  -gno-column-info  -gdwarf32  -gdwarf64
-gstatement-frontiers  -gno-statement-frontiers
-gvariable-location-views  -gno-variable-location-views
-ginternal-reset-location-views  -gno-internal-reset-location-views
-ginline-points  -gno-inline-points
-gvms -gz[=type]
-gsplit-dwarf  -gdescribe-dies  -gno-describe-dies
-fdebug-prefix-map=old=new  -fdebug-types-section
-fno-eliminate-unused-debug-types
-femit-struct-debug-baseonly  -femit-struct-debug-reduced
-femit-struct-debug-detailed[=spec-list]
-fno-eliminate-unused-debug-symbols  -femit-class-debug-always
-fno-merge-debug-strings  -fno-dwarf2-cfi-asm
```

```
-fvar-tracking  -fvar-tracking-assignments  -fvar-tracking-uninit
--debug
```

Optimization Options

See Section 3.12 [Options that Control Optimization], page 194.

```
-faggressive-loop-optimizations
-falign-functions[=n[:m:[n2[:m2]]]]
-falign-jumps[=n[:m:[n2[:m2]]]]
-falign-labels[=n[:m:[n2[:m2]]]]
-falign-loops[=n[:m:[n2[:m2]]]]
-fmin-function-alignment=[n]
-fno-allocation-dce -fallow-store-data-races
-fassociative-math  -fauto-profile  -fauto-profile[=path]
-fauto-profile-inlining -fauto-inc-dec  -fbranch-probabilities
-fcaller-saves
-fcombine-stack-adjustments  -fconserve-stack
-ffold-mem-offsets
-fcompare-elim  -fcprop-registers  -fcrossjumping
-fcse-follow-jumps  -fcse-skip-blocks  -fcx-fortran-rules
-fcx-limited-range -fcx-method
-fdata-sections  -fdce  -fdelayed-branch
-fdelete-null-pointer-checks  -fdep-fusion -fdevirtualize
-fdevirtualize-speculatively  -fdevirtualize-at-ltrans  -fdse
-fearly-inlining  -fexcess-precision=style
-fexpensive-optimizations  -fext-dce
-ffast-math  -ffat-lto-objects  -ffinite-loops
-ffinite-math-only  -ffloat-store
-fforward-propagate  -ffp-contract=style  -ffp-int-builtin-inexact
-ffunction-sections
-fgcse  -fgcse-after-reload  -fgcse-las  -fgcse-lm  -fgraphite-identity
-fgcse-sm  -fhoist-adjacent-loads  -fif-conversion
-fif-conversion2  -findirect-inlining
-finline-atomics  -finline-functions  -finline-functions-called-once
-finline-limit=n  -finline-small-functions
-finline-stringops[=fn]
-fipa-modref -fipa-cp  -fipa-cp-clone
-fipa-bit-cp  -fipa-vrp  -fipa-pta  -fipa-profile  -fipa-pure-const
-fipa-reference  -fipa-reference-addressable -fipa-reorder-for-locality
-fipa-sra  -fipa-stack-alignment
-fipa-icf  -fipa-icf-functions  -fipa-icf-variables
-fira-algorithm=algorithm
-flate-combine-instructions -flifetime-dse -flive-patching=level
-fira-region=region  -fira-hoist-pressure
-fira-loop-pressure  -fno-ira-share-save-slots
-fno-ira-share-spill-slots
-fisolate-erroneous-paths-dereference  -fisolate-erroneous-paths-attribute
-fivopts  -fkeep-inline-functions  -fkeep-static-functions
-fkeep-static-consts  -flimit-function-alignment  -flive-range-shrinkage
-floop-block  -floop-interchange  -floop-strip-mine
-floop-unroll-and-jam  -floop-nest-optimize
-floop-parallelize-all  -flra-remat  -flto  -flto-compression-level
-flto-partition=alg -flto-incremental=path
-flto-incremental-cache-size=n -fmalloc-dce -fmerge-all-constants
-fmerge-constants  -fmodulo-sched  -fmodulo-sched-allow-regmoves
-fmove-loop-invariants  -fmove-loop-stores  -fno-branch-count-reg
-fno-defer-pop  -fno-function-cse
-fno-guess-branch-probability  -fno-inline  -fno-math-errno  -fno-peephole
-fno-peephole2  -fno-printf-return-value  -fno-sched-interblock
```

```
-fno-sched-spec  -fno-signed-zeros
-fno-toplevel-reorder  -fno-trapping-math  -fno-zero-initialized-in-bss
-fomit-frame-pointer  -foptimize-crc  -foptimize-sibling-calls
-fpartial-inlining  -fpeel-loops  -fpredictive-commoning
-fprefetch-loop-arrays
-fprofile-correction
-fprofile-use  -fprofile-use=path -fprofile-partial-training
-fprofile-values -fprofile-reorder-functions
-freciprocal-math  -free  -frename-registers  -freorder-blocks
-freorder-blocks-algorithm=algorithm
-freorder-blocks-and-partition  -freorder-functions
-frerun-cse-after-loop  -freschedule-modulo-scheduled-loops
-frounding-math  -fsave-optimization-record
-fsched2-use-superblocks  -fsched-pressure
-fsched-spec-load  -fsched-spec-load-dangerous
-fsched-stalled-insns-dep[=n]  -fsched-stalled-insns[=n]
-fsched-group-heuristic  -fsched-critical-path-heuristic
-fsched-spec-insn-heuristic  -fsched-rank-heuristic
-fsched-last-insn-heuristic  -fsched-dep-count-heuristic
-fschedule-fusion
-fschedule-insns  -fschedule-insns2  -fsection-anchors
-fselective-scheduling  -fselective-scheduling2
-fsel-sched-pipelining  -fsel-sched-pipelining-outer-loops
-fsemantic-interposition  -fshrink-wrap  -fshrink-wrap-separate
-fsignaling-nans
-fsingle-precision-constant  -fsplit-ivs-in-unroller  -fsplit-loops
-fsplit-paths
-fsplit-wide-types  -fsplit-wide-types-early  -fssa-backprop  -fssa-phiopt
-fstdarg-opt  -fstore-merging  -fstrict-aliasing -fipa-strict-aliasing
-fthread-jumps  -ftracer  -ftree-bit-ccp
-ftree-builtin-call-dce  -ftree-ccp  -ftree-ch  -ftree-coalesce-vars
-ftree-copy-prop  -ftree-cselim  -ftree-dce  -ftree-dominator-opts
-ftree-dse  -ftree-forwprop  -ftree-fre  -fcode-hoisting
-ftree-loop-if-convert  -ftree-loop-im
-ftree-phiprop  -ftree-loop-distribution  -ftree-loop-distribute-patterns
-ftree-loop-ivcanon  -ftree-loop-linear  -ftree-loop-optimize
-ftree-loop-vectorize
-ftree-parallelize-loops[=n]  -ftree-pre  -ftree-partial-pre  -ftree-pta
-ftree-reassoc  -ftree-scev-cprop  -ftree-sink  -ftree-slsr  -ftree-sra
-ftree-switch-conversion  -ftree-tail-merge
-ftree-ter  -ftree-vectorize  -ftree-vrp  -ftrivial-auto-var-init
-funconstrained-commons -funit-at-a-time  -funroll-all-loops
-funroll-loops -funsafe-math-optimizations  -funswitch-loops
-fipa-ra  -fvariable-expansion-in-unroller  -fvect-cost-model  -fvpt
-fweb  -fwhole-program  -fwpa  -fuse-linker-plugin -fzero-call-used-regs
--param name=value
-O  -O0  -O1  -O2  -O3  -Os  -Ofast  -Og  -Oz  --optimize
```

Program Instrumentation Options

See Section 3.13 [Program Instrumentation Options], page 275.

```
-p  -pg  -fprofile-arcs  -coverage  -ftest-coverage
-fcondition-coverage
-fpath-coverage
-fprofile  -fprofile-abs-path
-fprofile-dir=path  -fprofile-generate  -fprofile-generate=path
-fprofile-info-section  -fprofile-info-section=name
-fprofile-note=path -fprofile-prefix-path=path
-fprofile-update=method -fprofile-filter-files=regex
```

```
-fprofile-exclude-files=regex
-fprofile-reproducible=[multithreaded|parallel-runs|serial]
-fsanitize=style -fsanitize-recover -fsanitize-recover=style
-fsanitize-trap -fsanitize-trap=style
-fasan-shadow-offset=number -fsanitize-sections=s1,s2,...
-fsanitize-undefined-trap-on-error -fbounds-check -fcf-protection
-fcf-protection=[full|branch|return|none|check]
-fharden-compares -fharden-conditional-branches -fhardened
-fharden-control-flow-redundancy -fhardcfr-skip-leaf
-fhardcfr-check-exceptions -fhardcfr-check-returning-calls
-fhardcfr-check-noreturn-calls=[always|no-xthrow|nothrow|never]
-fstack-protector -fstack-protector-all -fstack-protector-strong
-fstack-protector-explicit -fstack-check
-fstack-limit-register=reg -fstack-limit-symbol=sym
-fno-stack-limit -fsplit-stack
-fstrub=disable -fstrub=strict -fstrub=relaxed
-fstrub=all -fstrub=at-calls -fstrub=internal
-fvtable-verify=[std|preinit|none]
-fvtv-counts -fvtv-debug
-finstrument-functions -finstrument-functions-once
-finstrument-functions-exclude-function-list=sym,sym,...
-finstrument-functions-exclude-file-list=file,file,...
-fprofile-prefix-map=old=new
-fpatchable-function-entry=N[,M]
--coverage --profile
```

Preprocessor Options

See Section 3.14 [Options Controlling the Preprocessor], page 297.

```
-C -CC -Dmacro[=defn]
-dD -dI -dM -dN -dU
-fdebug-cpp -fdirectives-only -fdollars-in-identifiers
-fexec-charset=charset -fextended-identifiers
-finput-charset=charset
-fmacro-prefix-map=old=new -fmax-include-depth=depth
-fno-canonical-system-headers -fpch-deps -fpch-preprocess
-fpreprocessed -ftabstop=width -ftrack-macro-expansion
-fwide-exec-charset=charset -fworking-directory
-H -imacros file -include file
-M -MD -MF -MG -MM -MMD -MP -MQ -MT -Mno-modules
-no-integrated-cpp -P -pthread -remap
-traditional -traditional-cpp -trigraphs
-Umacro -undef
-Wp,option -Xpreprocessor option
--comments --comments-in-macros
--define-macro=macro[=defn]
--dependencies --dump=letters
--imacros=file --include=file
--no-integrated-cpp --no-line-commands
--print-missing-file-dependencies
--traditional --traditional-cpp --trigraphs --trace-includes
--undefine-macro=macro
--user-dependencies --write-dependencies --write-user-dependencies
```

Assembler Options

See Section 3.15 [Passing Options to the Assembler], page 305.

```
-Wa,option -Xassembler option
--for-assembler=option
```

Linker Options

See Section 3.16 [Options for Linking], page 305.

```
object-file-name -flink-libatomic  -fuse-ld=linker  -llibrary
-nostartfiles  -nodefaultlibs  -nolibc  -nostdlib  -nostdlib++
-e entry
-pie  -pthread  -r  -rdynamic
-s  -static  -static-pie  -static-libgcc  -static-libstdc++
-static-libasan  -static-libtsan  -static-liblsan  -static-libubsan
-shared  -shared-libgcc  -symbolic
-T script  -Wl,option  -Xlinker option
-u symbol
-Tbss=addr  -Tdata=addr  -Ttext=addr
-N  -n  -t  -Z  -z keyword
--entry=entry  --for-linker=option
--force-link=symbol  --no-standard-library
--pie  --static  --static-pie  --symbolic
```

Directory Options

See Section 3.17 [Options for Directory Search], page 312.

```
-Bprefix  -Idir  -I-
-idirafter dir
-imacros file  -imultilib dir
-iplugindir=dir  -iprefix file
-iquote dir  -isysroot dir  -isystem dir
-iwithprefix dir  -iwithprefixbefore dir
-Ldir  -no-canonical-prefixes  --no-sysroot-suffix
-nostdinc  -nostdinc++
--embed-dir=dir  --embed-directory=dir
--include-barrier  --include-directory=dir
--include-directory-after=dir  --include-prefix=prefix
--include-with-prefix=prefix  --include-with-prefix-after=prefix
--include-with-prefix-before=prefix
--no-canonical-prefixes  --no-standard-includes
--prefix=prefix  --sysroot=dir
```

Code Generation Options

See Section 3.18 [Options for Code Generation Conventions], page 315.

```
-fcall-saved-reg  -fcall-used-reg
-ffixed-reg  -fexceptions
-fnon-call-exceptions  -fdelete-dead-exceptions  -funwind-tables
-fasynchronous-unwind-tables
-fno-gnu-unique
-finhibit-size-directive  -fcommon  -fno-ident
-fpcc-struct-return  -fpic  -fPIC  -fpie  -fPIE  -fno-plt
-fno-jump-tables -fno-bit-tests
-frecord-gcc-switches
-freg-struct-return  -fshort-enums  -fshort-wchar
-fverbose-asm  -fpack-struct[=n]
-fleading-underscore  -ftls-model=model
-fstack-reuse=reuse_level
-ftrampolines -ftrampoline-impl=[stack|heap]
-ftrapv  -fwrapv
-fvisibility=[default|internal|hidden|protected]
-fstrict-volatile-bitfields  -fsync-libcalls
-fzero-init-padding-bits=value
-Qy  -Qn
```

Developer Options

See Section 3.19 [GCC Developer Options], page 326.

```
-dletters  -dumpspecs  -dumpmachine  -dumpversion
-dumpfullversion  -fcallgraph-info[=su,da]
-fchecking  -fchecking=n
-fdbg-cnt-list  -fdbg-cnt=counter-value-list
-fdisable-ipa-pass_name
-fdisable-rtl-pass_name
-fdisable-rtl-pass-name=range-list
-fdisable-tree-pass_name
-fdisable-tree-pass-name=range-list
-fdump-debug  -fdump-earlydebug
-fdump-noaddr  -fdump-unnumbered  -fdump-unnumbered-links
-fdump-final-insns[=file]
-fdump-internal-locations
-fdump-ipa-all  -fdump-ipa-cgraph  -fdump-ipa-inline
-fdump-lang-all
-fdump-lang-switch
-fdump-lang-switch-options
-fdump-lang-switch-options=filename
-fdump-passes
-fdump-rtl-pass  -fdump-rtl-pass=filename
-fdump-statistics
-fdump-tree-all
-fdump-tree-switch
-fdump-tree-switch-options
-fdump-tree-switch-options=filename
-fcompare-debug[=opts]  -fcompare-debug-second
-fenable-kind-pass
-fenable-kind-pass=range-list
-fira-verbose=n
-flto-report  -flto-report-wpa  -fmem-report-wpa
-fmem-report  -fpre-ipa-mem-report  -fpost-ipa-mem-report
-fopt-info  -fopt-info-options[=file]
-fmultiflags  -fprofile-report
-frandom-seed=string  -fsched-verbose=n
-fsel-sched-verbose  -fsel-sched-dump-cfg  -fsel-sched-pipelining-verbose
-fstats  -fstack-usage  -ftime-report  -ftime-report-details
-fvar-tracking-assignments-toggle  -gtoggle
-print-file-name=library  -print-libgcc-file-name
-print-multi-directory  -print-multi-lib  -print-multi-os-directory
-print-multiarch
-print-prog-name=program  -print-search-dirs  -Q
-print-sysroot  -print-sysroot-headers-suffix
-save-temps  -save-temps=cwd  -save-temps=obj  -time[=file]
--dump=letters
--print-file-name=library  --print-libgcc-file-file-name
--print-multi-directory  --print-multi-lib  --print-multi-os-directory
--print-multiarch  --print-prog-name=program
--print-search-dirs  --print-sysroot  --print-sysroot-headers-suffix
--save-temps
```

Machine-Dependent Options

See Section 3.20 [Machine-Dependent Options], page 345.

AArch64 Options (Section 3.20.1 [AArch64 Options], page 345)

```
-mabi=name  -mbig-endian  -mlittle-endian
```

```
-menable-sysreg-checking
-mgeneral-regs-only
-mcmodel=tiny  -mcmodel=small  -mcmodel=large
-mstrict-align  -momit-leaf-frame-pointer
-mtls-dialect=desc  -mtls-dialect=traditional
-mtls-size=size  -mtp=name
-mfix-cortex-a53-835769  -mfix-cortex-a53-843419
-mlow-precision-recip-sqrt  -mlow-precision-sqrt  -mlow-precision-div
-mmax-vectorization  -mautovec-preference=name
-mpc-relative-literal-loads
-msign-return-address=scope
-mbranch-protection=features
-mharden-sls=opts
-march=name  -mcpu=name  -mtune=name
-moverride=string
-mstack-protector-guard=guard  -mstack-protector-guard-reg=sysreg
-mstack-protector-guard-offset=offset  -mtrack-speculation
-moutline-atomics  -mearly-ra  -mearly-ldp-fusion  -mlate-ldp-fusion
-msve-vector-bits=bits
```

Adapteva Epiphany Options (Section 3.20.2 [Adapteva Epiphany Options], page 356)

```
-mhalf-reg-file  -mprefer-short-insn-regs
-mbranch-cost=num  -mcmove  -mnops=num  -msoft-cmpsf
-msplit-lohi  -mpost-inc  -mpost-modify  -mstack-offset=num
-mround-nearest  -mlong-calls  -mshort-calls  -msmall16
-mfp-mode=mode  -mmay-round-for-trunc  -mfp-iarith
-mvect-double  -max-vect-align=num
-msplit-vecmove-early  -m1reg-reg
```

AMD GCN Options (Section 3.20.3 [AMD GCN Options], page 359)

```
-march=gpu -mtune=gpu
-mgang-private-size=bytes
-msram-ecc=[on|off|any]
-mxnack=[on|off|any]
-Wopenacc-dims
```

ARC Options (Section 3.20.4 [ARC Options], page 361)

```
-mbarrel-shifter  -mjli-always
-mcpu=cpu  -mA6  -mARC600  -mA7  -mARC700
-mdpfp  -mdpfp-compact  -mdpfp-fast  -mno-dpfp-lrsr
-mea  -mno-mpy  -mmul32x16  -mmul64  -matomic
-mnorm  -mspfp  -mspfp-compact  -mspfp-fast  -msimd  -msoft-float  -mswap
-mcrc  -mdsp-packa  -mdvbf  -mlock  -mmac-d16  -mmac-24  -mrtsc  -mswape
-mtelephony  -mxy  -misize  -mannotate-align  -marclinux  -marclinux_prof
-mlong-calls  -mmedium-calls  -msdata  -mirq-ctrl-saved
-mrgf-banked-regs  -mlpc-width=width  -G num
-mvolatile-cache  -mtp-regno=regno
-malign-call  -mauto-modify-reg  -mbbit-peephole  -mno-brcc
-mcase-vector-pcrel  -mcompact-casesi  -mno-cond-exec  -mearly-cbranchsi
-mexpand-adddi  -mindexed-loads  -mlra  -mlra-priority-none
-mlra-priority-compact -mlra-priority-noncompact  -mmillicode
-mmixed-code  -mq-class  -mRcq  -mRcw  -msize-level=level
-mtune=cpu  -mmultcost=num  -mcode-density-frame
-munalign-prob-threshold=probability  -mmpy-option=multo
-mdiv-rem  -mcode-density  -mll64  -mfpu=fpu  -mrf16  -mbranch-index
```

ARM Options (Section 3.20.5 [ARM Options], page 371)

```
-mapcs-frame  -mapcs
```

```
-mabi=name
-mgeneral-regs-only  -mno-sched-prolog
-mlittle-endian  -mbig-endian
-mbe8  -mbe32
-mfloat-abi=name
-mfp16-format=name
-mthumb-interwork
-mcpu=name  -march=name  -mfpu=name  -mtune=name
-mstructure-size-boundary=n
-mabort-on-noreturn  -mlong-calls
-msingle-pic-base  -mpic-register=reg
-mpic-data-is-text-relative
-mnop-fun-dllimport
-mpoke-function-name
-mthumb  -marm
-mtpcs-frame  -mtpcs-leaf-frame
-mcaller-super-interworking  -mcallee-super-interworking
-mtp=name  -mtls-dialect=dialect
-mword-relocations
-mfix-cortex-m3-ldrd
-mfix-cortex-a57-aes-1742098
-mfix-cortex-a72-aes-1655431
-munaligned-access
-mslow-flash-data
-masm-syntax-unified
-mrestrict-it
-mpure-code
-mcmse
-mfix-cmse-cve-2021-35465
-mstack-protector-guard=guard
-mstack-protector-guard-offset=offset
-mfdpic
-mbranch-protection=features
```

AVR Options (Section 3.20.6 [AVR Options], page 388)

```
-mmcu=mcu  -mabsdata  -maccumulate-args  -mcvt
-mbranch-cost=cost  -mfuse-add=level  -mfuse-move=level
-mfuse-move2  -mcall-prologues  -mgas-isr-prologues  -mint8  -mflmap
-mdouble=bits  -mlong-double=bits  -mno-call-main
-mn_flash=size  -mfract-convert-truncate  -mno-interrupts
-mmain-is-OS_task  -mrelax  -mrmw  -mstrict-X  -mtiny-stack
-mrodata-in-ram  -msplit-bit-shift  -msplit-ldst  -mshort-calls
-mskip-bug  -muse-nonzero-bits  -nodevicelib  -nodevicespecs
-Waddr-space-convert  -Wmisspelled-isr
```

Blackfin Options (Section 3.20.7 [Blackfin Options], page 401)

```
-mcpu=cpu[-sirevision]
-msim  -momit-leaf-frame-pointer
-mspecld-anomaly  -mcsync-anomaly
-mlow-64k  -mstack-check-l1  -mid-shared-library
-mleaf-id-shared-library
-mshared-library-id=n
-msep-data  -mlong-calls
-mfast-fp  -minline-plt  -mmulticore  -mcorea  -mcoreb  -msdram
-micplb
```

C6X Options (Section 3.20.8 [C6X Options], page 404)

```
-mbig-endian  -mlittle-endian  -march=cpu
-msim  -msdata=sdata-type -mdsbt -mlong-calls
```

CRIS Options (Section 3.20.9 [CRIS Options], page 405)

```
-mcpu=cpu  -march=cpu
-mtune=cpu -mmax-stack-frame=n
-metrax4  -metrax100  -mpdebug  -mcc-init  -mno-side-effects
-mstack-align  -mdata-align  -mconst-align
-m32-bit  -m16-bit  -m8-bit  -mno-prologue-epilogue
-mbest-lib-options  -moverride-best-lib-options
-mtrap-using-break8  -mtrap-unaligned-atomic
-munaligned-atomic-may-use-library
-sim  -sim2
-mmul-bug-workaround
```

C-SKY Options (Section 3.20.10 [C-SKY Options], page 406)

```
-march=arch  -mcpu=cpu
-mbig-endian  -mlittle-endian
-mfpu=fpu  -mdouble-float  -mfdivdu
-mfloat-abi=name
-melrw  -mistack  -mmp  -mcp  -mcache  -msecurity  -mtrust
-mdsp  -medsp  -mvdsp
-mdiv  -msmart  -mhigh-registers  -manchor
-mpushpop  -mmultiple-stld  -mconstpool  -mstack-size  -mccrt
-mbranch-cost=n  -msched-prolog -msim
```

Cygwin and MinGW Options (Section 3.20.11 [Cygwin and MinGW Options], page 409)

```
-mconsole  -mcrtdll=library  -mdll
-mnop-fun-dllimport  -mthreads
-municode  -mwin32  -mwindows  -fno-set-stack-executable
-fwritable-relocated-rdata  -mpe-aligned-commons
```

Darwin Options (Section 3.20.12 [Darwin Options], page 411)

```
-all_load  -allowable_client  -arch name
-arch_errors_fatal  -asm_macosx_version_min=version
-bind_at_load  -bundle  -bundle_loader
-client_name  -compatibility_version  -current_version
-dead_strip
-dependency-file  -dylib_file  -dylinker  -dylinker_install_name
-dynamic  -dynamiclib  -exported_symbols_list
-fapple-kext  -fconstant-cfstrings  -ffix-and-continue
-filelist  -findirect-data  -flat_namespace  -force_cpusubtype_ALL
-force_flat_namespace  -framework name  -gfull  -gused
-headerpad_max_install_names  -iframework
-image_base  -init symbol-name  -install_name  -keep_private_externs
-matt-stubs  -mconstant-cfstrings  -mdynamic-no-pic
-mfix-and-continue  -mkernel  -mmacosx-version-min=version
-mone-byte-bool  -msymbol-stubs  -mtarget-linker[=]version
-nodefaultexport  -nodefaultrpaths
-pagezero_size  -preload  -read_only_relocs
-sectalign  -sectcreate
-seg_addr_table
-seg1addr  -segaddr
-segprot  -segs_read_only_addr  -segs_read_write_addr
-sub_library  -sub_umbrella
-twolevel_namespace  -twolevel_namespace_hints
-umbrella  -undefined  -unexported_symbols_list
-weak_framework name  -weak_reference_mismatches
-whatsloaded  -whyload
-F  -ObjC  -ObjC++  -Wnonportable-cfstrings
```

DEC Alpha Options (Section 3.20.13 [DEC Alpha Options], page 415)

```
-mno-fp-regs  -msoft-float
-mieee  -mieee-with-inexact  -mieee-conformant
-mfp-trap-mode=mode  -mfp-rounding-mode=mode
-mtrap-precision=mode  -mbuild-constants
-mcpu=cpu-type  -mtune=cpu-type
-mbwx  -mmax  -mfix  -mcix
-msafe-bwa  -msafe-partial
-mfloat-vax  -mfloat-ieee
-mexplicit-relocs  -msmall-data  -mlarge-data
-msmall-text  -mlarge-text
-mmemory-latency=time
-mtls-kernel  -mtls-size=bitsize
-mlong-double-128  -mlong-double-64
```

eBPF Options (Section 3.20.14 [eBPF Options], page 420)

```
-mbig-endian  -mlittle-endian
-mframe-limit=bytes  -mxbpf  -mco-re  -mjmpext  -mjmp32
-malu32  -mv3-atomics  -mbswap  -msdiv  -msmov  -mcpu=version
-masm=dialect  -minline-memops-threshold=bytes
```

FR30 Options (Section 3.20.15 [FR30 Options], page 422)

```
-msmall-model  -mno-lsim
```

FRV Options (Section 3.20.16 [FRV Options], page 422)

```
-mgpr-32  -mgpr-64  -mfpr-32  -mfpr-64
-mhard-float  -msoft-float
-malloc-cc  -mfixed-cc  -mdword  -mdouble  -mmedia  -mmuladd
-mfdpic  -minline-plt  -mgprel-ro  -multilib-library-pic
-mlinked-fp  -mlong-calls  -malign-labels
-mlibrary-pic  -macc-4  -macc-8
-mpack  -mno-eflags  -mno-cond-move
-mno-optimize-membar  -mno-scc  -mno-cond-exec
-mno-vliw-branch  -mno-multi-cond-exec  -mno-nested-cond-exec
-mtomcat-stats
-mTLS  -mtls
-mcpu=cpu
```

FT32 Options (Section 3.20.17 [FT32 Options], page 425)

```
-msim  -mnodiv  -mft32b  -mcompress  -mnopm
```

GNU/Linux Options (Section 3.20.18 [GNU/Linux Options], page 425)

```
-mglibc  -muclibc  -mmusl  -mbionic  -mandroid
-tno-android-cc  -tno-android-ld
```

H8/300 Options (Section 3.20.19 [H8/300 Options], page 426)

```
-mrelax  -mh  -ms  -mn  -mexr  -mno-exr  -mint32  -malign-300
```

HPPA Options (Section 3.20.20 [HPPA Options], page 426)

```
-march=architecture-type
-matomic-libcalls  -mbig-switch
-mcaller-copies  -mdisable-fpregs  -mdisable-indexing
-mordered  -mfast-indirect-calls  -mgas  -mgnu-ld   -mhp-ld
-mfixed-range=register-range
-mcoherent-ldcw -mjump-in-delay  -mlinker-opt  -mlong-calls
-mlong-load-store  -mno-atomic-libcalls  -mno-disable-fpregs
-mno-disable-indexing  -mno-fast-indirect-calls  -mno-gas
-mno-jump-in-delay  -mno-long-load-store
-mno-portable-runtime  -mno-soft-float
-mno-space-regs  -msoft-float  -mpa-risc-1-0
```

-mpa-risc-1-1 -mpa-risc-2-0 -mportable-runtime
-mschedule=*cpu-type* -mspace-regs -msoft-mult -msio -mwsio
-munix=*unix-std* -nolibdld -static -threads

IA-64 Options (Section 3.20.21 [IA-64 Options], page 430)

-mbig-endian -mlittle-endian -mgnu-as -mgnu-ld -mno-pic
-mvolatile-asm-stop -mregister-names -msdata -mno-sdata
-mconstant-gp -mauto-pic -mfused-madd
-minline-float-divide-min-latency
-minline-float-divide-max-throughput
-mno-inline-float-divide
-minline-int-divide-min-latency
-minline-int-divide-max-throughput
-mno-inline-int-divide
-minline-sqrt-min-latency -minline-sqrt-max-throughput
-mno-inline-sqrt
-mdwarf2-asm -mearly-stop-bits
-mfixed-range=*register-range* -mtls-size=*tls-size*
-mtune=*cpu-type* -milp32 -mlp64
-msched-br-data-spec -msched-ar-data-spec -msched-control-spec
-msched-br-in-data-spec -msched-ar-in-data-spec -msched-in-control-spec
-msched-spec-ldc -msched-spec-control-ldc
-msched-prefer-non-data-spec-insns -msched-prefer-non-control-spec-insns
-msched-stop-bits-after-every-cycle -msched-count-spec-in-critical-path
-msel-sched-dont-check-control-spec -msched-fp-mem-deps-zero-cost
-msched-max-memory-insns-hard-limit -msched-max-memory-insns=*max-insns*

LM32 Options (Section 3.20.22 [LM32 Options], page 433)

-mbarrel-shift-enabled -mdivide-enabled -mmultiply-enabled
-msign-extend-enabled -muser-enabled

LoongArch Options (Section 3.20.23 [LoongArch Options], page 434)

-march=*arch-type* -mtune=*tune-type* -mabi=*base-abi-type*
-mfpu=*fpu-type* -msimd=*simd-type*
-msoft-float -msingle-float -mdouble-float -mlsx -mno-lsx -mlasx -mno-lasx
-mbranch-cost=*n* -maddr-reg-reg-cost=*n* -mcheck-zero-division
-mno-check-zero-division -mbreak-code=*code*
-mcond-move-int -mno-cond-move-int
-mcond-move-float -mno-cond-move-float
-memcpy -mno-memcpy -mstrict-align -mno-strict-align -G *num*
-mmax-inline-memcpy-size=*n*
-mexplicit-relocs=*style* -mexplicit-relocs -mno-explicit-relocs
-mdirect-extern-access -mno-direct-extern-access
-mcmodel=*code-model* -mrelax -mpass-mrelax-to-as
-mrecip -mrecip=*opt* -mfrecipe -mno-frecipe -mdiv32 -mno-div32
-mlam-bh -mno-lam-bh -mlamcas -mno-lamcas -mld-seq-sa -mno-ld-seq-sa
-mscq -mno-scq -mtls-dialect=*opt*
-mannotate-tablejump -mno-annotate-tablejump

M32C Options (Section 3.20.24 [M32C Options], page 440)

-mcpu=*cpu* -msim -memregs=*number*

M32R/D Options (Section 3.20.25 [M32R/D Options], page 440)

-m32r2 -m32rx -m32r
-mdebug
-malign-loops -mno-align-loops
-missue-rate=*number*
-mbranch-cost=*number*
-mmodel=*code-size-model-type*
-msdata=*sdata-type*

```
-mno-flush-func  -mflush-func=name
-mno-flush-trap  -mflush-trap=number
-G num
```

M680x0 Options (Section 3.20.26 [M680x0 Options], page 442)

```
-march=arch  -mcpu=cpu  -mtune=tune
-m68000  -m68020  -m68020-40  -m68020-60  -m68030  -m68040
-m68060  -mcpu32  -m5200  -m5206e  -m528x  -m5307  -m5407
-mcfv4e  -mbitfield  -mno-bitfield  -mc68000  -mc68020
-mnobitfield  -mrtd  -mno-rtd  -mdiv  -mno-div  -mshort
-mno-short  -mhard-float  -m68881  -msoft-float  -mpcrel
-malign-int  -mstrict-align  -msep-data  -mno-sep-data
-mshared-library-id=n  -mid-shared-library  -mno-id-shared-library
-mxgot  -mno-xgot  -mlong-jump-table-offsets
```

MCore Options (Section 3.20.27 [MCore Options], page 447)

```
-mhardlit  -mno-hardlit  -mdiv  -mno-div  -mrelax-immediates
-mno-relax-immediates  -mwide-bitfields  -mno-wide-bitfields
-m4byte-functions  -mno-4byte-functions  -mcallgraph-data
-mno-callgraph-data  -mslow-bytes  -mno-slow-bytes  -mno-lsim
-mlittle-endian  -mbig-endian  -m210  -m340  -mstack-increment
```

MicroBlaze Options (Section 3.20.28 [MicroBlaze Options], page 448)

```
-msoft-float  -mhard-float  -msmall-divides  -mcpu=cpu
-mmemcpy  -mxl-soft-mul  -mxl-soft-div  -mxl-barrel-shift
-mxl-pattern-compare  -mxl-stack-check  -mxl-gp-opt  -mno-clearbss
-mxl-multiply-high  -mxl-float-convert  -mxl-float-sqrt
-mbig-endian  -mlittle-endian  -mxl-reorder  -mxl-mode-app-model
-mpic-data-is-text-relative
```

MIPS Options (Section 3.20.29 [MIPS Options], page 449)

```
-EL  -EB  -march=arch  -mtune=arch
-mips1  -mips2  -mips3  -mips4  -mips32  -mips32r2  -mips32r3  -mips32r5
-mips32r6  -mips64  -mips64r2  -mips64r3  -mips64r5  -mips64r6
-mips16  -mno-mips16  -mflip-mips16
-minterlink-compressed  -mno-interlink-compressed
-minterlink-mips16  -mno-interlink-mips16
-mabi=abi  -mabicalls  -mno-abicalls
-mshared  -mno-shared  -mplt  -mno-plt  -mxgot  -mno-xgot
-mgp32  -mgp64  -mfp32  -mfpxx  -mfp64  -mhard-float  -msoft-float
-mno-float  -msingle-float  -mdouble-float
-modd-spreg  -mno-odd-spreg
-mabs=mode  -mnan=encoding
-mdsp  -mno-dsp  -mdspr2  -mno-dspr2
-mmcu  -mmno-mcu
-meva  -mno-eva
-mvirt  -mno-virt
-mxpa  -mno-xpa
-mcrc  -mno-crc
-mginv  -mno-ginv
-mmicromips  -mno-micromips
-mmsa  -mno-msa
-mloongson-mmi  -mno-loongson-mmi
-mloongson-ext  -mno-loongson-ext
-mloongson-ext2  -mno-loongson-ext2
-mfpu=fpu-type
-msmartmips  -mno-smartmips
-mpaired-single  -mno-paired-single  -mdmx  -mno-mdmx
-mips3d  -mno-mips3d  -mmt  -mno-mt  -mllsc  -mno-llsc
-mlong64  -mlong32  -msym32  -mno-sym32
```

```
-Gnum  -mlocal-sdata  -mno-local-sdata
-mextern-sdata  -mno-extern-sdata  -mgpopt  -mno-gopt
-membedded-data  -mno-embedded-data
-muninit-const-in-rodata  -mno-uninit-const-in-rodata
-mcode-readable=setting
-msplit-addresses  -mno-split-addresses
-mexplicit-relocs  -mno-explicit-relocs
-mexplicit-relocs=release
-mcheck-zero-division  -mno-check-zero-division
-mdivide-traps  -mdivide-breaks
-mload-store-pairs  -mno-load-store-pairs
-mstrict-align  -mno-strict-align
-mno-unaligned-access  -munaligned-access
-mmemcpy  -mno-memcpy  -mlong-calls  -mno-long-calls
-mmad  -mno-mad  -mimadd  -mno-imadd  -mfused-madd  -mno-fused-madd  -nocpp
-mfix-24k  -mno-fix-24k
-mfix-r4000  -mno-fix-r4000  -mfix-r4400  -mno-fix-r4400
-mfix-r5900  -mno-fix-r5900
-mfix-r10000  -mno-fix-r10000  -mfix-rm7000  -mno-fix-rm7000
-mfix-vr4120  -mno-fix-vr4120
-mfix-vr4130  -mno-fix-vr4130  -mfix-sb1  -mno-fix-sb1
-mflush-func=func  -mno-flush-func
-mbranch-cost=num  -mbranch-likely  -mno-branch-likely
-mcompact-branches=policy
-mfp-exceptions  -mno-fp-exceptions
-mvr4130-align  -mno-vr4130-align  -msynci  -mno-synci
-mlxc1-sxc1  -mno-lxc1-sxc1  -mmadd4  -mno-madd4
-mrelax-pic-calls  -mno-relax-pic-calls  -mmcount-ra-address
-mframe-header-opt  -mno-frame-header-opt
```

MMIX Options (Section 3.20.30 [MMIX Options], page 464)

```
-mlibfuncs  -mno-libfuncs  -mepsilon  -mno-epsilon  -mabi=gnu
-mabi=mmixware  -mzero-extend  -mknuthdiv  -mtoplevel-symbols
-melf  -mbranch-predict  -mno-branch-predict  -mbase-addresses
-mno-base-addresses  -msingle-exit  -mno-single-exit
```

MN10300 Options (Section 3.20.31 [MN10300 Options], page 465)

```
-mmult-bug  -mno-mult-bug
-mno-am33  -mam33  -mam33-2  -mam34
-mtune=cpu-type
-mreturn-pointer-on-d0
-mno-crt0  -mrelax  -mliw  -msetlb
```

Moxie Options (Section 3.20.32 [Moxie Options], page 466)

```
-meb  -mel  -mmul.x  -mno-crt0
```

MSP430 Options (Section 3.20.33 [MSP430 Options], page 467)

```
-msim  -masm-hex  -mmcu=  -mcpu=  -mlarge  -msmall  -mrelax
-mwarn-mcu
-mcode-region=  -mdata-region=
-msilicon-errata=  -msilicon-errata-warn=
-mhwmult=  -minrt  -mtiny-printf  -mmax-inline-shift=
```

NDS32 Options (Section 3.20.34 [NDS32 Options], page 469)

```
-mbig-endian  -mlittle-endian
-mreduced-regs  -mfull-regs
-mcmov  -mno-cmov
-mext-perf  -mno-ext-perf
-mext-perf2  -mno-ext-perf2
-mext-string  -mno-ext-string
```

-mv3push -mno-v3push
-m16bit -mno-16bit
-misr-vector-size=*num*
-mcache-block-size=*num*
-march=*arch*
-mcmodel=*code-model*
-mctor-dtor -mrelax

Nvidia PTX Options (Section 3.20.35 [Nvidia PTX Options], page 471)

-m64 -mmainkernel -moptimize

OpenRISC Options (Section 3.20.36 [OpenRISC Options], page 472)

-mboard=*name* -mnewlib -mhard-mul -mhard-div
-msoft-mul -msoft-div
-msoft-float -mhard-float -mdouble-float -munordered-float
-mcmov -mror -mrori -msext -msfimm -mshftimm
-mcmodel=*code-model*

PDP-11 Options (Section 3.20.37 [PDP-11 Options], page 473)

-mfpu -msoft-float -mac0 -mno-ac0 -m40 -m45 -m10
-mint32 -mno-int16 -mint16 -mno-int32
-msplit -munix-asm -mdec-asm -mgnu-asm -mlra

PowerPC Options See RS/6000 and PowerPC Options.

PRU Options (Section 3.20.39 [PRU Options], page 474)

-mmcu=*mcu* -minrt -mno-relax -mloop
-mmul -mfillzero -mabi=*variant*

RISC-V Options (Section 3.20.40 [RISC-V Options], page 475)

-mbranch-cost=*N-instruction*
-mplt -mno-plt
-mabi=*ABI-string*
-mfdiv -mno-fdiv
-mfence-tso -mno-fence-tso
-mdiv -mno-div
-misa-spec=*ISA-spec-string*
-march=*ISA-string|Profiles|Profiles_ISA-string|CPU/processor string*
-mtune=*processor-string*
-mpreferred-stack-boundary=*num*
-msmall-data-limit=*N-bytes*
-msave-restore -mno-save-restore
-mshorten-memrefs -mno-shorten-memrefs
-mstrict-align -mno-strict-align
-mcmodel=medlow -mcmodel=medany -mcmodel=large
-mexplicit-relocs -mno-explicit-relocs
-mrelax -mno-relax
-mriscv-attribute -mno-riscv-attribute
-malign-data=*type*
-mbig-endian -mlittle-endian
-mstack-protector-guard=*guard* -mstack-protector-guard-reg=*reg*
-mstack-protector-guard-offset=*offset*
-mcsr-check -mno-csr-check
-mmovcc -mno-movcc
-minline-atomics -mno-inline-atomics
-minline-strlen -mno-inline-strlen
-minline-strcmp -mno-inline-strcmp
-minline-strncmp -mno-inline-strncmp
-mtls-dialect=desc -mtls-dialect=trad

RL78 Options (Section 3.20.41 [RL78 Options], page 491)

```
-msim  -mmul=none  -mmul=g13  -mmul=g14  -mallregs
-mcpu=g10  -mcpu=g13  -mcpu=g14  -mg10  -mg13  -mg14
-m64bit-doubles  -m32bit-doubles  -msave-mduc-in-interrupts
```

RS/6000 and PowerPC Options (Section 3.20.42 [RS/6000 and PowerPC Options], page 493)

```
-mcpu=cpu-type
-mtune=cpu-type
-mcmodel=code-model
-mpowerpc64
-maltivec  -mno-altivec
-mpowerpc-gpopt  -mno-powerpc-gpopt
-mpowerpc-gfxopt  -mno-powerpc-gfxopt
-mmfcrf  -mno-mfcrf  -mpopcntb  -mno-popcntb  -mpopcntd  -mno-popcntd
-mfprnd  -mno-fprnd
-mcmpb  -mno-cmpb  -mhard-dfp  -mno-hard-dfp
-mfull-toc   -mminimal-toc  -mno-fp-in-toc  -mno-sum-in-toc
-m64  -m32  -mxl-compat  -mno-xl-compat  -mpe
-malign-power  -malign-natural
-msoft-float  -mhard-float  -mmultiple  -mno-multiple
-mupdate  -mno-update
-mavoid-indexed-addresses  -mno-avoid-indexed-addresses
-mfused-madd  -mno-fused-madd  -mbit-align  -mno-bit-align
-mstrict-align  -mno-strict-align  -mrelocatable
-mno-relocatable  -mrelocatable-lib  -mno-relocatable-lib
-mtoc  -mno-toc  -mlittle  -mlittle-endian  -mbig  -mbig-endian
-mdynamic-no-pic  -mswdiv  -msingle-pic-base
-mprioritize-restricted-insns=priority
-msched-costly-dep=dependence_type
-minsert-sched-nops=scheme
-mcall-aixdesc  -mcall-eabi  -mcall-freebsd
-mcall-linux  -mcall-netbsd  -mcall-openbsd
-mcall-sysv  -mcall-sysv-eabi  -mcall-sysv-noeabi
-mtraceback=traceback_type
-maix-struct-return  -msvr4-struct-return
-mabi=abi-type  -msecure-plt  -mbss-plt
-msplit-patch-nops
-mlongcall  -mno-longcall  -mpltseq  -mno-pltseq
-mblock-move-inline-limit=num
-mblock-compare-inline-limit=num
-mblock-compare-inline-loop-limit=num
-mno-block-ops-unaligned-vsx
-mstring-compare-inline-limit=num
-misel  -mno-isel
-mvrsave  -mno-vrsave
-mmulhw  -mno-mulhw
-mdlmzb  -mno-dlmzb
-mprototype  -mno-prototype
-msim  -mmvme  -mads  -myellowknife  -memb  -msdata
-msdata=opt  -mreadonly-in-sdata  -mvxworks  -G num
-mrecip  -mrecip=opt  -mno-recip  -mrecip-precision
-mno-recip-precision
-mveclibabi=type  -mfriz  -mno-friz
-mpointers-to-nested-functions  -mno-pointers-to-nested-functions
-msave-toc-indirect  -mno-save-toc-indirect
-mpower8-fusion  -mno-mpower8-fusion
-mcrypto  -mno-crypto  -mhtm  -mno-htm
-mquad-memory  -mno-quad-memory
```

```
-mquad-memory-atomic  -mno-quad-memory-atomic
-mcompat-align-parm  -mno-compat-align-parm
-mfloat128  -mno-float128  -mfloat128-hardware  -mno-float128-hardware
-mgnu-attribute  -mno-gnu-attribute
-mstack-protector-guard=guard -mstack-protector-guard-reg=reg
-mstack-protector-guard-offset=offset -mprefixed -mno-prefixed
-mpcrel -mno-pcrel -mmma -mno-mma -mrop-protect -mno-rop-protect
-mprivileged -mno-privileged
```

RX Options (Section 3.20.43 [RX Options], page 508)

```
-m64bit-doubles  -m32bit-doubles  -fpu  -nofpu
-mcpu=
-mbig-endian-data  -mlittle-endian-data
-msmall-data
-msim  -mno-sim
-mas100-syntax  -mno-as100-syntax
-mrelax
-mmax-constant-size=
-mint-register=
-mpid
-mallow-string-insns  -mno-allow-string-insns
-mjsr
-mno-warn-multiple-fast-interrupts
-msave-acc-in-interrupts
```

S/390 and zSeries Options (Section 3.20.44 [S/390 and zSeries Options], page 511)

```
-mtune=cpu-type  -march=cpu-type
-mhard-float  -msoft-float  -mhard-dfp  -mno-hard-dfp
-mlong-double-64  -mlong-double-128
-mbackchain  -mno-backchain  -mpacked-stack  -mno-packed-stack
-msmall-exec  -mno-small-exec  -mmvcle  -mno-mvcle
-m64  -m31  -mdebug  -mno-debug  -mesa  -mzarch
-mhtm  -mvx  -mzvector
-mtpf-trace  -mno-tpf-trace  -mtpf-trace-skip  -mno-tpf-trace-skip
-mfused-madd  -mno-fused-madd
-mwarn-framesize  -mwarn-dynamicstack  -mstack-size  -mstack-guard
-mhotpatch=halfwords,halfwords
```

SH Options (Section 3.20.45 [SH Options], page 516)

```
-m1  -m2  -m2e
-m2a-nofpu  -m2a-single-only  -m2a-single  -m2a
-m3  -m3e
-m4-nofpu  -m4-single-only  -m4-single  -m4
-m4a-nofpu  -m4a-single-only  -m4a-single  -m4a  -m4al
-mb  -ml  -mdalign  -mrelax
-mbigtable  -mfmovd  -mrenesas  -mno-renesas  -mnomacsave
-mieee  -mno-ieee  -mbitops  -misize  -minline-ic_invalidate  -mpadstruct
-mprefergot  -musermode  -multcost=number  -mdiv=strategy
-mdivsi3_libfunc=name  -mfixed-range=register-range
-maccumulate-outgoing-args
-matomic-model=atomic-model
-mbranch-cost=num  -mzdcbranch  -mno-zdcbranch
-mcbranch-force-delay-slot
-mfused-madd  -mno-fused-madd  -mfsca  -mno-fsca  -mfsrra  -mno-fsrra
-mpretend-cmove  -mtas
```

Solaris 2 Options (Section 3.20.46 [Solaris 2 Options], page 522)

```
-mclear-hwcap  -mno-clear-hwcap  -mimpure-text  -mno-impure-text
```

-pthreads

SPARC Options (Section 3.20.47 [SPARC Options], page 522)

```
-mcpu=cpu-type
-mtune=cpu-type
-mcmodel=code-model
-mmemory-model=mem-model
-m32  -m64  -mapp-regs  -mno-app-regs
-mfaster-structs  -mno-faster-structs  -mflat  -mno-flat
-mfpu  -mno-fpu  -mhard-float  -msoft-float
-mhard-quad-float  -msoft-quad-float
-mstack-bias  -mno-stack-bias
-mstd-struct-return  -mno-std-struct-return
-munaligned-doubles  -mno-unaligned-doubles
-muser-mode  -mno-user-mode
-mv8plus  -mno-v8plus  -mvis  -mno-vis
-mvis2  -mno-vis2
-mvis3  -mno-vis3  -mvis3b  -mno-vis3b
-mvis4  -mno-vis4  -mvis4b  -mno-vis4b
-mcbcond  -mno-cbcond  -mfmaf  -mno-fmaf  -mfsmuld  -mno-fsmuld
-mpopc  -mno-popc  -msubxc  -mno-subxc
-mfix-at697f  -mfix-ut699  -mfix-ut700  -mfix-gr712rc
```

System V Options (Section 3.20.48 [System V Options], page 529)

```
-YP,paths  -Ym,dir
```

V850 Options (Section 3.20.49 [V850 Options], page 529)

```
-mlong-calls  -mno-long-calls  -mep  -mno-ep
-mprolog-function  -mno-prolog-function  -mspace
-mtda=n  -msda=n  -mzda=n
-mapp-regs  -mno-app-regs
-mdisable-callt  -mno-disable-callt
-mv850e2v3  -mv850e2  -mv850e1  -mv850es
-mv850e  -mv850  -mv850e3v5
-mloop
-mrelax
-mlong-jumps
-msoft-float
-mhard-float
-mgcc-abi
-mrh850-abi
-mbig-switch
```

VAX Options (Section 3.20.50 [VAX Options], page 531)

```
-munix  -mgnu  -md  -md-float  -mg  -mg-float  -mlra
```

Visium Options (Section 3.20.51 [Visium Options], page 532)

```
-mdebug  -msim  -mfpu  -mno-fpu  -mhard-float  -msoft-float
-mcpu=cpu-type  -mtune=cpu-type  -msv-mode  -muser-mode
```

VMS Options (Section 3.20.52 [VMS Options], page 533)

```
-mvms-return-codes  -mdebug-main=prefix  -mmalloc64
-mpointer-size=size
```

VxWorks Options (Section 3.20.53 [VxWorks Options], page 533)

```
-mrtp  -msmp  -non-static  -Bstatic  -Bdynamic
-Xbind-lazy  -Xbind-now
```

x86 Options (Section 3.20.54 [x86 Options], page 534)

```
-mtune=cpu-type  -march=cpu-type
```

```
-mtune-ctrl=feature-list  -mdump-tune-features  -mno-default
-mfpmath=unit
-masm=dialect  -mno-fancy-math-387
-mno-fp-ret-in-387  -m80387  -mhard-float  -msoft-float
-mno-wide-multiply  -mrtd  -malign-double
-mpreferred-stack-boundary=num
-mincoming-stack-boundary=num
-mcld  -mcx16  -msahf  -mmovbe  -mcrc32 -mmwait
-mrecip  -mrecip=opt
-mvzeroupper  -mprefer-avx128  -mprefer-vector-width=opt
-mpartial-vector-fp-math
-mmove-max=bits -mstore-max=bits
-mnoreturn-no-callee-saved-registers
-mmmx  -msse  -msse2  -msse3  -mssse3  -msse4.1  -msse4.2  -msse4  -mavx
-mavx2  -mavx512f  -mavx512cd  -mavx512vl
-mavx512bw  -mavx512dq  -mavx512ifma  -mavx512vbmi  -msha  -maes
-mpclmul  -mfsgsbase  -mrdrnd  -mf16c  -mfma  -mpconfig  -mwbnoinvd
-mptwrite  -mclflushopt  -mclwb  -mxsavec  -mxsaves
-msse4a  -m3dnow  -m3dnowa  -mpopcnt  -mabm  -mbmi  -mtbm  -mfma4  -mxop
-madx  -mlzcnt  -mbmi2  -mfxsr  -mxsave  -mxsaveopt  -mrtm  -mhle  -mlwp
-mmwaitx  -mclzero  -mpku  -mthreads  -mgfni  -mvaes  -mwaitpkg
-mshstk -mmanual-endbr -mcet-switch -mforce-indirect-call
-mavx512vbmi2 -mavx512bf16 -menqcmd
-mvpclmulqdq  -mavx512bitalg  -mmovdiri  -mmovdir64b  -mavx512vpopcntdq
-mavx512vnni  -mprfchw  -mrdpid
-mrdseed  -msgx -mavx512vp2intersect -mserialize -mtsxldtrk
-mamx-tile  -mamx-int8  -mamx-bf16 -muintr -mhreset -mavxvnni -mamx-fp8
-mavx512fp16 -mavxifma -mavxvnniint8 -mavxneconvert -mcmpccxadd -mamx-fp16
-mprefetchi -mraoint -mamx-complex -mavxvnniint16 -msm3 -msha512 -msm4 -mapxf
-musermsr -mavx10.1 -mavx10.2 -mamx-avx512 -mamx-tf32 -mmovrs -mamx-movrs
-mcldemote  -mms-bitfields  -mno-align-stringops  -minline-all-stringops
-minline-stringops-dynamically  -mstringop-strategy=alg
-mkl -mwidekl
-mmemcpy-strategy=strategy  -mmemset-strategy=strategy
-mpush-args  -maccumulate-outgoing-args  -m128bit-long-double
-m96bit-long-double  -mlong-double-64  -mlong-double-80  -mlong-double-128
-mregparm=num  -msseregparm
-mveclibabi=type  -mvect8-ret-in-mem
-mpc32  -mpc64  -mpc80  -mdaz-ftz -mstackrealign
-momit-leaf-frame-pointer  -mno-red-zone  -mno-tls-direct-seg-refs
-mcmodel=code-model  -mabi=name  -maddress-mode=mode
-m32  -m64  -mx32  -m16  -miamcu  -mlarge-data-threshold=num
-msse2avx  -mfentry  -mrecord-mcount  -mnop-mcount  -m8bit-idiv
-minstrument-return=type -mfentry-name=name -mfentry-section=name
-mavx256-split-unaligned-load  -mavx256-split-unaligned-store
-malign-data=type  -mstack-protector-guard=guard
-mstack-protector-guard-reg=reg
-mstack-protector-guard-offset=offset
-mstack-protector-guard-symbol=symbol
-mgeneral-regs-only  -mcall-ms2sysv-xlogues -mrelax-cmpxchg-loop
-mindirect-branch=choice  -mfunction-return=choice
-mindirect-branch-register -mharden-sls=choice
-mindirect-branch-cs-prefix -mneeded -mno-direct-extern-access
-munroll-only-small-loops -mlam=choice
```

x86 Windows Options See Cygwin and MinGW Options.

Xstormy16 Options (Section 3.20.56 [Xstormy16 Options], page 567)

```
-msim
```

Xtensa Options (Section 3.20.57 [Xtensa Options], page 567)

```
-mconst16  -mno-const16
-mfused-madd  -mno-fused-madd
-mforce-no-pic
-mserialize-volatile  -mno-serialize-volatile
-mtext-section-literals  -mno-text-section-literals
-mauto-litpools  -mno-auto-litpools
-mtarget-align  -mno-target-align
-mlongcalls  -mno-longcalls
-mabi=abi-type
-mextra-l32r-costs=cycles
-mstrict-align  -mno-strict-align
```

zSeries Options See S/390 and zSeries Options.

3.2 Options Controlling the Kind of Output

Compilation can involve up to four stages: preprocessing, compilation proper, assembly and linking, always in that order. GCC is capable of preprocessing and compiling several files either into several assembler input files, or into one assembler input file; then each assembler input file produces an object file, and linking combines all the object files (those newly compiled, and those specified as input) into an executable file.

For any given input file, the file name suffix determines what kind of compilation is done:

`file.c` C source code that must be preprocessed.

`file.i` C source code that should not be preprocessed.

`file.ii` C++ source code that should not be preprocessed.

`file.m` Objective-C source code. Note that you must link with the `libobjc` library to make an Objective-C program work.

`file.mi` Objective-C source code that should not be preprocessed.

`file.mm`
`file.M` Objective-C++ source code. Note that you must link with the `libobjc` library to make an Objective-C++ program work. Note that '`.M`' refers to a literal capital M.

`file.mii` Objective-C++ source code that should not be preprocessed.

`file.h` C, C++, Objective-C or Objective-C++ header file to be turned into a precompiled header (default), or C, C++ header file to be turned into an Ada spec (via the `-fdump-ada-spec` switch).

`file.cc`
`file.cp`
`file.cxx`
`file.cpp`
`file.CPP`
`file.c++`
`file.C` C++ source code that must be preprocessed. Note that in '`.cxx`', the last two letters must both be literally '`x`'. Likewise, '`.C`' refers to a literal capital C.

file.mm
file.M Objective-C++ source code that must be preprocessed.

file.mii Objective-C++ source code that should not be preprocessed.

file.hh
file.H
file.hp
file.hxx
file.hpp
file.HPP
file.h++
file.tcc C++ header file to be turned into a precompiled header or Ada spec.

file.f
file.for
file.ftn
file.fi Fixed form Fortran source code that should not be preprocessed.

file.F
file.FOR
file.fpp
file.FPP
file.FTN Fixed form Fortran source code that must be preprocessed (with the traditional preprocessor).

file.f90
file.f95
file.f03
file.f08
file.fii Free form Fortran source code that should not be preprocessed.

file.F90
file.F95
file.F03
file.F08 Free form Fortran source code that must be preprocessed (with the traditional preprocessor).

file.cob

file.COB

file.cbl

file.CBL COBOL source code.

file.go Go source code.

file.d D source code.

file.di D interface file.

file.dd D documentation code (Ddoc).

file.ads
: Ada source code file that contains a library unit declaration (a declaration of a package, subprogram, or generic, or a generic instantiation), or a library unit renaming declaration (a package, generic, or subprogram renaming declaration). Such files are also called *specs*.

file.adb
: Ada source code file containing a library unit body (a subprogram or package body). Such files are also called *bodies*.

file.s
: Assembler code.

file.S
file.sx
: Assembler code that must be preprocessed.

other
: An object file to be fed straight into linking. Any file name with no recognized suffix is treated this way.

You can specify the input language explicitly with the `-x` option:

`-x` *language*
`--language=`*language*
`--language` *language*
: Specify explicitly the *language* for the following input files (rather than letting the compiler choose a default based on the file name suffix). This option applies to all following input files until the next `-x` option. Possible values for *language* are:

```
c  c-header  cpp-output
c++  c++-header  c++-system-header c++-user-header c++-cpp-output
objective-c  objective-c-header  objective-c-cpp-output
objective-c++ objective-c++-header objective-c++-cpp-output
assembler  assembler-with-cpp
ada
cobol
d
f77  f77-cpp-input f95  f95-cpp-input
go
```

Note that `-x` does not imply a particular language standard. For example `-x f77` may also require `-std=legacy` for some older source codes.

`-x none`
: Turn off any specification of a language, so that subsequent files are handled according to their file name suffixes (as if `-x` has not been used at all).

If you only want some of the stages of compilation, you can use `-x` (or filename suffixes) to tell `gcc` where to start, and one of the options `-c`, `-S`, or `-E` to say where `gcc` is to stop. Note that some combinations (for example, '`-x cpp-output -E`') instruct `gcc` to do nothing at all.

`-c`
`--compile`
: Compile or assemble the source files, but do not link. The linking stage simply is not done. The ultimate output is in the form of an object file for each source file.

By default, the object file name for a source file is made by replacing the suffix '`.c`', '`.i`', '`.s`', etc., with '`.o`'.

Unrecognized input files, not requiring compilation or assembly, are ignored.

`-S`
`--assemble`

Stop after the stage of compilation proper; do not assemble. The output is in the form of an assembler code file for each non-assembler input file specified.

By default, the assembler file name for a source file is made by replacing the suffix '`.c`', '`.i`', etc., with '`.s`'.

Input files that don't require compilation are ignored.

`-E`
`--preprocess`

Stop after the preprocessing stage; do not run the compiler proper. The output is in the form of preprocessed source code, which is sent to the standard output.

Input files that don't require preprocessing are ignored.

`-o` *`file`*
`--output=`*`file`*
`--output` *`file`*

Place the primary output in file *file*. This applies to whatever sort of output is being produced, whether it be an executable file, an object file, an assembler file or preprocessed C code.

If `-o` is not specified, the default is to put an executable file in `a.out`, the object file for *`source.suffix`* in *`source`*`.o`, its assembler file in *`source`*`.s`, a precompiled header file in *`source.suffix`*`.gch`, and all preprocessed C source on standard output.

Though `-o` names only the primary output, it also affects the naming of auxiliary and dump outputs. See the examples below. Unless overridden, both auxiliary outputs and dump outputs are placed in the same directory as the primary output. In auxiliary outputs, the suffix of the input file is replaced with that of the auxiliary output file type; in dump outputs, the suffix of the dump file is appended to the input file suffix. In compilation commands, the base name of both auxiliary and dump outputs is that of the primary output; in compile and link commands, the primary output name, minus the executable suffix, is combined with the input file name. If both share the same base name, disregarding the suffix, the result of the combination is that base name, otherwise, they are concatenated, separated by a dash.

```
gcc -c foo.c ...
```

will use `foo.o` as the primary output, and place aux outputs and dumps next to it, e.g., aux file `foo.dwo` for `-gsplit-dwarf`, and dump file `foo.c.???r.final` for `-fdump-rtl-final`.

If a non-linker output file is explicitly specified, aux and dump files by default take the same base name:

```
gcc -c foo.c -o dir/foobar.o ...
```

will name aux outputs `dir/foobar.*` and dump outputs `dir/foobar.c.*`.

A linker output will instead prefix aux and dump outputs:

```
gcc foo.c bar.c -o dir/foobar ...
```

will generally name aux outputs `dir/foobar-foo.*` and `dir/foobar-bar.*`, and dump outputs `dir/foobar-foo.c.*` and `dir/foobar-bar.c.*`.

The one exception to the above is when the executable shares the base name with the single input:

```
gcc foo.c -o dir/foo ...
```

in which case aux outputs are named `dir/foo.*` and dump outputs named `dir/foo.c.*`.

The location and the names of auxiliary and dump outputs can be adjusted by the options `-dumpbase`, `-dumpbase-ext`, `-dumpdir`, `-save-temps=cwd`, and `-save-temps=obj`.

`-dumpbase` *dumpbase*
`--dumpbase` *dumpbase*

This option sets the base name for auxiliary and dump output files. It does not affect the name of the primary output file. Intermediate outputs, when preserved, are not regarded as primary outputs, but as auxiliary outputs:

```
gcc -save-temps -S foo.c
```

saves the (no longer) temporary preprocessed file in `foo.i`, and then compiles to the (implied) output file `foo.s`, whereas:

```
gcc -save-temps -dumpbase save-foo -c foo.c
```

preprocesses to in `save-foo.i`, compiles to `save-foo.s` (now an intermediate, thus auxiliary output), and then assembles to the (implied) output file `foo.o`.

Absent this option, dump and aux files take their names from the input file, or from the (non-linker) output file, if one is explicitly specified: dump output files (e.g. those requested by `-fdump-*` options) with the input name suffix, and aux output files (those requested by other non-dump options, e.g. `-save-temps`, `-gsplit-dwarf`, `-fcallgraph-info`) without it.

Similar suffix differentiation of dump and aux outputs can be attained for explicitly-given `-dumpbase basename.suf` by also specifying `-dumpbase-ext .suf`.

If *dumpbase* is explicitly specified with any directory component, any *dumppfx* specification (e.g. `-dumpdir` or `-save-temps=*`) is ignored, and instead of appending to it, *dumpbase* fully overrides it:

```
gcc foo.c -c -o dir/foo.o -dumpbase alt/foo \
  -dumpdir pfx- -save-temps=cwd ...
```

creates auxiliary and dump outputs named `alt/foo.*`, disregarding `dir/` in `-o`, the `./` prefix implied by `-save-temps=cwd`, and `pfx-` in `-dumpdir`.

When `-dumpbase` is specified in a command that compiles multiple inputs, or that compiles and then links, it may be combined with *dumppfx*, as specified under `-dumpdir`. Then, each input file is compiled using the combined *dumppfx*, and default values for *dumpbase* and *auxdropsuf* are computed for each input file:

```
gcc foo.c bar.c -c -dumpbase main ...
```

creates `foo.o` and `bar.o` as primary outputs, and avoids overwriting the auxiliary and dump outputs by using the *dumpbase* as a prefix, creating auxiliary and dump outputs named `main-foo.*` and `main-bar.*`.

An empty string specified as *dumpbase* avoids the influence of the output basename in the naming of auxiliary and dump outputs during compilation, computing default values :

```
gcc -c foo.c -o dir/foobar.o -dumpbase '' ...
```

will name aux outputs `dir/foo.*` and dump outputs `dir/foo.c.*`. Note how their basenames are taken from the input name, but the directory still defaults to that of the output.

The empty-string dumpbase does not prevent the use of the output basename for outputs during linking:

```
gcc foo.c bar.c -o dir/foobar -dumpbase '' -flto ...
```

The compilation of the source files will name auxiliary outputs `dir/foo.*` and `dir/bar.*`, and dump outputs `dir/foo.c.*` and `dir/bar.c.*`. LTO recompilation during linking will use `dir/foobar.` as the prefix for dumps and auxiliary files.

`-dumpbase-ext` *auxdropsuf*
`--dumpbase-ext` *auxdropsuf*

When forming the name of an auxiliary (but not a dump) output file, drop trailing *auxdropsuf* from *dumpbase* before appending any suffixes. If not specified, this option defaults to the suffix of a default *dumpbase*, i.e., the suffix of the input file when `-dumpbase` is not present in the command line, or *dumpbase* is combined with *dumppfx*.

```
gcc foo.c -c -o dir/foo.o -dumpbase x-foo.c -dumpbase-ext .c ...
```

creates `dir/foo.o` as the main output, and generates auxiliary outputs in `dir/x-foo.*`, taking the location of the primary output, and dropping the `.c` suffix from the *dumpbase*. Dump outputs retain the suffix: `dir/x-foo.c.*`.

This option is disregarded if it does not match the suffix of a specified *dumpbase*, except as an alternative to the executable suffix when appending the linker output base name to *dumppfx*, as specified below:

```
gcc foo.c bar.c -o main.out -dumpbase-ext .out ...
```

creates `main.out` as the primary output, and avoids overwriting the auxiliary and dump outputs by using the executable name minus *auxdropsuf* as a prefix, creating auxiliary outputs named `main-foo.*` and `main-bar.*` and dump outputs named `main-foo.c.*` and `main-bar.c.*`.

`-dumpdir` *dumppfx*
`--dumpdir` *dumppfx*

When forming the name of an auxiliary or dump output file, use *dumppfx* as a prefix:

```
gcc -dumpdir pfx- -c foo.c ...
```

creates `foo.o` as the primary output, and auxiliary outputs named `pfx-foo.*`, combining the given *dumppfx* with the default *dumpbase* derived from the default primary output, derived in turn from the input name. Dump outputs also take the input name suffix: `pfx-foo.c.*`.

If *dumppfx* is to be used as a directory name, it must end with a directory separator:

```
gcc -dumpdir dir/ -c foo.c -o obj/bar.o ...
```

creates `obj/bar.o` as the primary output, and auxiliary outputs named `dir/bar.*`, combining the given *dumppfx* with the default *dumpbase* derived from the primary output name. Dump outputs also take the input name suffix: `dir/bar.c.*`.

It defaults to the location of the output file, unless the output file is a special file like `/dev/null`. Options `-save-temps=cwd` and `-save-temps=obj` override this default, just like an explicit `-dumpdir` option. In case multiple such options are given, the last one prevails:

```
gcc -dumpdir pfx- -c foo.c -save-temps=obj ...
```

outputs `foo.o`, with auxiliary outputs named `foo.*` because `-save-temps=*` overrides the *dumppfx* given by the earlier `-dumpdir` option. It does not matter that `=obj` is the default for `-save-temps`, nor that the output directory is implicitly the current directory. Dump outputs are named `foo.c.*`.

When compiling from multiple input files, if `-dumpbase` is specified, *dumpbase*, minus a *auxdropsuf* suffix, and a dash are appended to (or override, if containing any directory components) an explicit or defaulted *dumppfx*, so that each of the multiple compilations gets differently-named aux and dump outputs.

```
gcc foo.c bar.c -c -dumpdir dir/pfx- -dumpbase main ...
```

outputs auxiliary dumps to `dir/pfx-main-foo.*` and `dir/pfx-main-bar.*`, appending *dumpbase*- to *dumppfx*. Dump outputs retain the input file suffix: `dir/pfx-main-foo.c.*` and `dir/pfx-main-bar.c.*`, respectively. Contrast with the single-input compilation:

```
gcc foo.c -c -dumpdir dir/pfx- -dumpbase main ...
```

that, applying `-dumpbase` to a single source, does not compute and append a separate *dumpbase* per input file. Its auxiliary and dump outputs go in `dir/pfx-main.*`.

When compiling and then linking from multiple input files, a defaulted or explicitly specified *dumppfx* also undergoes the *dumpbase*- transformation above (e.g. the compilation of `foo.c` and `bar.c` above, but without `-c`). If neither `-dumpdir` nor `-dumpbase` are given, the linker output base name, minus *auxdropsuf*, if specified, or the executable suffix otherwise, plus a dash is appended to the default *dumppfx* instead. Note, however, that unlike earlier cases of linking:

```
gcc foo.c bar.c -dumpdir dir/pfx- -o main ...
```

does not append the output name `main` to *dumppfx*, because `-dumpdir` is explicitly specified. The goal is that the explicitly-specified *dumppfx* may contain the specified output name as part of the prefix, if desired; only an explicitly-specified `-dumpbase` would be combined with it, in order to avoid simply discarding a meaningful option.

When compiling and then linking from a single input file, the linker output base name will only be appended to the default *dumppfx* as above if it does not share the base name with the single input file name. This has been covered in single-input linking cases above, but not with an explicit `-dumpdir` that inhibits the combination, even if overridden by `-save-temps=*`:

```
gcc foo.c -dumpdir alt/pfx- -o dir/main.exe -save-temps=cwd ...
```

Auxiliary outputs are named `foo.*`, and dump outputs `foo.c.*`, in the current working directory as ultimately requested by `-save-temps=cwd`.

Summing it all up for an intuitive though slightly imprecise data flow: the primary output name is broken into a directory part and a basename part; *dumppfx* is set to the former, unless overridden by `-dumpdir` or `-save-temps=*`, and *dumpbase* is set to the latter, unless overriden by `-dumpbase`. If there are multiple inputs or linking, this *dumpbase* may be combined with *dumppfx* and taken from each input file. Auxiliary output names for each input are formed by combining *dumppfx*, *dumpbase* minus suffix, and the auxiliary output suffix; dump output names are only different in that the suffix from *dumpbase* is retained.

When it comes to auxiliary and dump outputs created during LTO recompilation, a combination of *dumppfx* and *dumpbase*, as given or as derived from the linker output name but not from inputs, even in cases in which this combination would not otherwise be used as such, is passed down with a trailing period replacing the compiler-added dash, if any, as a `-dumpdir` option to `lto-wrapper`; being involved in linking, this program does not normally get any `-dumpbase` and `-dumpbase-ext`, and it ignores them.

When running sub-compilers, `lto-wrapper` appends LTO stage names to the received *dumppfx*, ensures it contains a directory component so that it overrides any `-dumpdir`, and passes that as `-dumpbase` to sub-compilers.

`-v`
`--verbose`
: Print (on standard error output) the commands executed to run the stages of compilation. Also print the version number of the compiler driver program and of the preprocessor and the compiler proper.

`-###`
: Like `-v` except the commands are not executed and arguments are quoted unless they contain only alphanumeric characters or `./-_`. This is useful for shell scripts to capture the driver-generated command lines.

`--help`
: Print (on the standard output) a description of the command-line options understood by `gcc`. If the `-v` option is also specified then `--help` is also passed on to the various processes invoked by `gcc`, so that they can display the command-line options they accept. If the `-Wextra` option has also been specified (prior to the `--help` option), then command-line options that have no documentation associated with them are also displayed.

`--target-help`
: Print (on the standard output) a description of target-specific command-line options for each tool. For some targets extra target-specific information may also be printed.

`--help={class|[^]qualifier}[,...]`
: Print (on the standard output) a description of the command-line options understood by the compiler that fit into all specified classes and qualifiers. These are the supported classes:

'optimizers'
: Display all of the optimization options supported by the compiler.

'warnings'
: Display all of the options controlling warning messages produced by the compiler.

'target'
: Display target-specific options. Unlike the `--target-help` option however, target-specific options of the linker and assembler are not displayed. This is because those tools do not currently support the extended `--help=` syntax.

'params'
: Display the values recognized by the `--param` option.

language
: Display the options supported for *language*, where *language* is the name of one of the languages supported in this version of GCC. If an option is supported by all languages, one needs to select 'common' class.

'common'
: Display the options that are common to all languages.

These are the supported qualifiers:

'undocumented'
: Display only those options that are undocumented.

'joined'
: Display options taking an argument that appears after an equal sign in the same continuous piece of text, such as: '--help=target'.

'separate'
: Display options taking an argument that appears as a separate word following the original option, such as: '-o output-file'.

Thus for example to display all the undocumented target-specific switches supported by the compiler, use:

```
--help=target,undocumented
```

The sense of a qualifier can be inverted by prefixing it with the '^' character, so for example to display all binary warning options (i.e., ones that are either on or off and that do not take an argument) that have a description, use:

```
--help=warnings,^joined,^undocumented
```

The argument to `--help=` should not consist solely of inverted qualifiers.

Combining several classes is possible, although this usually restricts the output so much that there is nothing to display. One case where it does work, however, is when one of the classes is *target*. For example, to display all the target-specific optimization options, use:

```
--help=target,optimizers
```

The `--help=` option can be repeated on the command line. Each successive use displays its requested class of options, skipping those that have already been displayed. If `--help` is also specified anywhere on the command line then this takes precedence over any `--help=` option.

If the `-Q` option appears on the command line before the `--help=` option, then the descriptive text displayed by `--help=` is changed. Instead of describing the displayed options, an indication is given as to whether the option is enabled, disabled or set to a specific value (assuming that the compiler knows this at the point where the `--help=` option is used).

Here is a truncated example from the ARM port of `gcc`:

```
% gcc -Q -mabi=2 --help=target -c
The following options are target specific:
-mabi=                                2
-mabort-on-noreturn                   [disabled]
-mapcs                                [disabled]
```

The output is sensitive to the effects of previous command-line options, so for example it is possible to find out which optimizations are enabled at `-O2` by using:

```
-Q -O2 --help=optimizers
```

Alternatively you can discover which binary optimizations are enabled by `-O3` by using:

```
gcc -c -Q -O3 --help=optimizers > /tmp/O3-opts
gcc -c -Q -O2 --help=optimizers > /tmp/O2-opts
diff /tmp/O2-opts /tmp/O3-opts | grep enabled
```

`--version`
Display the version number and copyrights of the invoked GCC.

`-pass-exit-codes`
`--pass-exit-codes`
Normally the `gcc` program exits with the code of 1 if any phase of the compiler returns a non-success return code. If you specify `-pass-exit-codes`, the `gcc` program instead returns with the numerically highest error produced by any phase returning an error indication. The C, C++, and Fortran front ends return 4 if an internal compiler error is encountered.

`-pipe`
`--pipe` Use pipes rather than temporary files for communication between the various stages of compilation. This fails to work on some systems where the assembler is unable to read from a pipe; but the GNU assembler has no trouble.

`-specs=`*`file`*
`--specs=`*`file`*
`--specs` *`file`*
Process *file* after the compiler reads in the standard `specs` file, in order to override the defaults which the `gcc` driver program uses when determining what switches to pass to `cc1`, `cc1plus`, `as`, `ld`, etc. More than one `-specs=`*`file`* can be specified on the command line, and they are processed in order, from left to right. See Section 3.21 [Spec Files], page 570, for information about the format of the *file*.

`-wrapper` Invoke all subcommands under a wrapper program. The name of the wrapper program and its parameters are passed as a comma separated list.

```
gcc -c t.c -wrapper gdb,--args
```

This invokes all subprograms of `gcc` under '`gdb --args`', thus the invocation of `cc1` is '`gdb --args cc1 ...`'.

`-ffile-prefix-map=old=new`
When compiling files residing in directory *old*, record any references to them in the result of the compilation as if the files resided in directory *new* instead. Specifying this option is equivalent to specifying all the individual `-f*-prefix-map` options. This can be used to make reproducible builds that are location independent. Directories referenced by directives are not affected by these options. See also `-fmacro-prefix-map`, `-fdebug-prefix-map`, `-fprofile-prefix-map` and `-fcanon-prefix-map`.

`-fcanon-prefix-map`
For the `-f*-prefix-map` options normally comparison of *old* prefix against the filename that would be normally referenced in the result of the compilation is done using textual comparison of the prefixes, or ignoring character case for case insensitive filesystems and considering slashes and backslashes as equal on DOS based filesystems. The `-fcanon-prefix-map` causes such comparisons to be done on canonicalized paths of *old* and the referenced filename.

`-fplugin=name.so`
Load the plugin code in file *name*.so, assumed to be a shared object to be dlopen'd by the compiler. The base name of the shared object file is used to identify the plugin for the purposes of argument parsing (See `-fplugin-arg-name-key=value` below). Each plugin should define the callback functions specified in the Plugins API.

`-fplugin-arg-name-key=value`
Define an argument called *key* with a value of *value* for the plugin called *name*.

`-fdump-ada-spec[-slim]`
For C and C++ source and include files, generate corresponding Ada specs. See Section "Generating Ada Bindings for C and C++ headers" in *GNAT User's Guide*, which provides detailed documentation on this feature.

`-fada-spec-parent=unit`
In conjunction with `-fdump-ada-spec[-slim]` above, generate Ada specs as child units of parent *unit*.

`-fdump-go-spec=file`
For input files in any language, generate corresponding Go declarations in *file*. This generates Go `const`, `type`, `var`, and `func` declarations which may be a useful way to start writing a Go interface to code written in some other language.

`@file` Read command-line options from *file*. The options read are inserted in place of the original @*file* option. If *file* does not exist, or cannot be read, then the option will be treated literally, and not removed.

Options in *file* are separated by whitespace. A whitespace character may be included in an option by surrounding the entire option in either single or double quotes. Any character (including a backslash) may be included by prefixing the character to be included with a backslash. The *file* may itself contain additional @*file* options; any such options will be processed recursively.

3.3 Compiling C++ Programs

C++ source files conventionally use one of the suffixes '.C', '.cc', '.cpp', '.CPP', '.c++', '.cp', or '.cxx'; C++ header files often use '.hh', '.hpp', '.H', or (for shared template code) '.tcc'; preprocessed C++ files use the suffix '.ii'; and C++20 module interface units sometimes use '.ixx', '.cppm', '.cxxm', '.c++m', or '.ccm'.

GCC recognizes files with these names and compiles them as C++ programs even if you call the compiler the same way as for compiling C programs (usually with the name gcc).

However, the use of gcc does not add the C++ library. g++ is a program that calls GCC and automatically specifies linking against the C++ library. It treats '.c', '.h' and '.i' files as C++ source files instead of C source files unless -x is used. This program is also useful when precompiling a C header file with a '.h' extension for use in C++ compilations. On many systems, g++ is also installed with the name c++.

When you compile C++ programs, you may specify many of the same command-line options that you use for compiling programs in any language; or command-line options meaningful for C and related languages; or options that are meaningful only for C++ programs. See Section 3.4 [Options Controlling C Dialect], page 45, for explanations of options for languages related to C. See Section 3.5 [Options Controlling C++ Dialect], page 52, for explanations of options that are meaningful only for C++ programs.

3.4 Options Controlling C Dialect

The following options control the dialect of C (or languages derived from C, such as C++, Objective-C and Objective-C++) that the compiler accepts:

-ansi
--ansi
: In C mode, this is equivalent to -std=c90. In C++ mode, it is equivalent to -std=c++98.

-std=
: Determine the language standard. See Chapter 2 [Language Standards Supported by GCC], page 3, for details of these standard versions. This option is currently only supported when compiling C or C++.

The compiler can accept several base standards, such as 'c90' or 'c++98', and GNU dialects of those standards, such as 'gnu90' or 'gnu++98'. When a base standard is specified, the compiler accepts all programs following that standard plus those using GNU extensions that do not contradict it. For example, -std=c90 turns off certain features of GCC that are incompatible with ISO C90, such as the asm and typeof keywords, but not other GNU extensions that do not have a meaning in ISO C90, such as omitting the middle term of a ?: expression. On the other hand, when a GNU dialect of a standard is specified, all features supported by the compiler are enabled, even when those features change the meaning of the base standard. As a result, some strict-conforming programs may be rejected. The particular standard is used by -Wpedantic to identify which features are GNU extensions given that version of the standard. For example -std=gnu90 -Wpedantic warns about C++ style '//' comments, while -std=gnu99 -Wpedantic does not.

A value for this option must be provided; possible values are

'c90'
'c89'
'iso9899:1990'
: Support all ISO C90 programs (certain GNU extensions that conflict with ISO C90 are disabled). Same as `-ansi` for C code.

'iso9899:199409'
: ISO C90 as modified in amendment 1.

'c99'
'c9x'
'iso9899:1999'
'iso9899:199x'
: ISO C99. This standard is substantially completely supported, modulo bugs and floating-point issues (mainly but not entirely relating to optional C99 features from Annexes F and G). See `https://gcc.gnu.org/projects/c-status.html` for more information. The names '`c9x`' and '`iso9899:199x`' are deprecated.

'c11'
'c1x'
'iso9899:2011'
: ISO C11, the 2011 revision of the ISO C standard. This standard is substantially completely supported, modulo bugs, floating-point issues (mainly but not entirely relating to optional C11 features from Annexes F and G) and the optional Annexes K (Bounds-checking interfaces) and L (Analyzability). The name '`c1x`' is deprecated.

'c17'
'c18'
'iso9899:2017'
'iso9899:2018'
: ISO C17, the 2017 revision of the ISO C standard (published in 2018). This standard is same as C11 except for corrections of defects (all of which are also applied with `-std=c11`) and a new value of `__STDC_VERSION__`, and so is supported to the same extent as C11.

'c23'
'c2x'
'iso9899:2024'
: ISO C23, the 2023 revision of the ISO C standard (published in 2024). The name '`c2x`' is deprecated.

'c2y'
: The next version of the ISO C standard, still under development. The support for this version is experimental and incomplete.

'gnu90'
'gnu89'
: GNU dialect of ISO C90 (including some C99 features).

'gnu99'
'gnu9x'
: GNU dialect of ISO C99. The name '`gnu9x`' is deprecated.

'gnu11'
'gnu1x' GNU dialect of ISO C11. The name 'gnu1x' is deprecated.

'gnu17'
'gnu18' GNU dialect of ISO C17.

'gnu23'
'gnu2x' GNU dialect of ISO C23. This is the default for C code. The name 'gnu2x' is deprecated.

'gnu2y' The next version of the ISO C standard, still under development, plus GNU extensions. The support for this version is experimental and incomplete. The name 'gnu2x' is deprecated.

'c++98'
'c++03' The 1998 ISO C++ standard plus the 2003 technical corrigendum and some additional defect reports. Same as `-ansi` for C++ code.

'gnu++98'
'gnu++03' GNU dialect of `-std=c++98`.

'c++11'
'c++0x' The 2011 ISO C++ standard plus amendments. The name 'c++0x' is deprecated.

'gnu++11'
'gnu++0x' GNU dialect of `-std=c++11`. The name 'gnu++0x' is deprecated.

'c++14'
'c++1y' The 2014 ISO C++ standard plus amendments. The name 'c++1y' is deprecated.

'gnu++14'
'gnu++1y' GNU dialect of `-std=c++14`. The name 'gnu++1y' is deprecated.

'c++17'
'c++1z' The 2017 ISO C++ standard plus amendments. The name 'c++1z' is deprecated.

'gnu++17'
'gnu++1z' GNU dialect of `-std=c++17`. The name 'gnu++1z' is deprecated.

'c++20'
'c++2a' The 2020 ISO C++ standard plus amendments. C++20 modules support is still experimental and needs to be enabled with `-fmodules` option. The name 'c++2a' is deprecated.

'gnu++20'
'gnu++2a' GNU dialect of `-std=c++20`. This is the default for C++ code. C++20 modules support is still experimental and needs to be enabled with `-fmodules` option. The name 'gnu++2a' is deprecated.

'c++23'
'c++2b' The 2023 ISO C++ standard plus amendments (published in 2024). Support is experimental, and could change in incompatible ways in future releases. The name 'c++2b' is deprecated.

'gnu++23'
'gnu++2b' GNU dialect of `-std=c++23`. Support is experimental, and could change in incompatible ways in future releases. The name 'gnu++2b' is deprecated.

'c++2c'
'c++26' The next revision of the ISO C++ standard, planned for 2026. Support is highly experimental, and will almost certainly change in incompatible ways in future releases.

'gnu++2c'
'gnu++26' GNU dialect of `-std=c++2c`. Support is highly experimental, and will almost certainly change in incompatible ways in future releases.

`-aux-info` *filename*

Output to the given filename prototyped declarations for all functions declared and/or defined in a translation unit, including those in header files. This option is silently ignored in any language other than C.

Besides declarations, the file indicates, in comments, the origin of each declaration (source file and line), whether the declaration was implicit, prototyped or unprototyped ('I', 'N' for new or 'O' for old, respectively, in the first character after the line number and the colon), and whether it came from a declaration or a definition ('C' or 'F', respectively, in the following character). In the case of function definitions, a K&R-style list of arguments followed by their declarations is also provided, inside comments, after the declaration.

`-fno-asm` Do not recognize `asm`, `inline` or `typeof` as a keyword, so that code can use these words as identifiers. You can use the keywords `__asm__`, `__inline__` and `__typeof__` instead. In C, `-ansi` implies `-fno-asm`.

In C++, `inline` is a standard keyword and is not affected by this switch. You may want to use the `-fno-gnu-keywords` flag instead, which disables `typeof` but not `asm` and `inline`. In C99 mode (`-std=c99` or `-std=gnu99`), this switch only affects the `asm` and `typeof` keywords, since `inline` is a standard keyword in ISO C99. In C23 mode (`-std=c23` or `-std=gnu23`), this switch only affects the `asm` keyword, since `typeof` is a standard keyword in ISO C23.

`-fno-builtin`
`-fno-builtin-`*function*

Don't recognize built-in functions that do not begin with '__builtin_' as prefix. See Section 7.1 [Library Builtins], page 829, for details of the functions affected, including those which are not built-in functions when `-ansi` or `-std` options for strict ISO C conformance are used because they do not have an ISO standard meaning.

GCC normally generates special code to handle certain built-in functions more efficiently; for instance, calls to `alloca` may become single instructions which adjust the stack directly, and calls to `memcpy` may become inline copy loops. The resulting code is often both smaller and faster, but since the function calls no longer appear as such, you cannot set a breakpoint on those calls, nor can you change the behavior of the functions by linking with a different library.

In addition, when a function is recognized as a built-in function, GCC may use information about that function to warn about problems with calls to that function, or to generate more efficient code, even if the resulting code still contains calls to that function. For example, warnings are given with `-Wformat` for bad calls to `printf` when `printf` is built in and `strlen` is known not to modify global memory.

With the `-fno-builtin-function` option only the built-in function *function* is disabled. *function* must not begin with '`__builtin_`'. If a function is named that is not built-in in this version of GCC, this option is ignored. There is no corresponding `-fbuiltin-function` option; if you wish to enable built-in functions selectively when using `-fno-builtin` or `-ffreestanding`, you may define macros such as:

```
#define abs(n)          __builtin_abs ((n))
#define strcpy(d, s)    __builtin_strcpy ((d), (s))
```

`-fcond-mismatch`
: Allow conditional expressions with mismatched types in the second and third arguments. The value of such an expression is void. This option is not supported for C++.

`-ffreestanding`
: Assert that compilation targets a freestanding environment. This implies `-fno-builtin`. A freestanding environment is one in which the standard library may not exist, and program startup may not necessarily be at `main`. The most obvious example is an OS kernel. This is equivalent to `-fno-hosted`.

See Chapter 2 [Language Standards Supported by GCC], page 3, for details of freestanding and hosted environments.

`-fgimple`
: Enable parsing of function definitions marked with `__GIMPLE`. This is an experimental feature that allows unit testing of GIMPLE passes.

`-fgnu-tm`
: When the option `-fgnu-tm` is specified, the compiler generates code for the Linux variant of Intel's current Transactional Memory ABI specification document (Revision 1.1, May 6 2009). This is an experimental feature whose interface may change in future versions of GCC, as the official specification changes. Please note that not all architectures are supported for this feature.

For more information on GCC's support for transactional memory, See Section "The GNU Transactional Memory Library" in *GNU Transactional Memory Library*.

Note that the transactional memory feature is not supported with non-call exceptions (`-fnon-call-exceptions`).

`-fgnu89-inline`
: The option `-fgnu89-inline` tells GCC to use the traditional GNU semantics for `inline` functions when in C99 mode. See Section 6.9 [An Inline Function is As Fast As a Macro], page 750. Using this option is roughly equivalent to adding the `gnu_inline` function attribute to all inline functions (see Section 6.4.1 [Function Attributes], page 621).

The option `-fno-gnu89-inline` explicitly tells GCC to use the C99 semantics for `inline` when in C99 or gnu99 mode (i.e., it specifies the default behavior). This option is not supported in `-std=c90` or `-std=gnu90` mode.

The preprocessor macros `__GNUC_GNU_INLINE__` and `__GNUC_STDC_INLINE__` may be used to check which semantics are in effect for `inline` functions. See Section "Common Predefined Macros" in *The C Preprocessor*.

`-fhosted`

Assert that compilation targets a hosted environment. This implies `-fbuiltin`. A hosted environment is one in which the entire standard library is available, and in which `main` has a return type of `int`. Examples are nearly everything except a kernel. This is equivalent to `-fno-freestanding`.

`-flax-vector-conversions`

Allow implicit conversions between vectors with differing numbers of elements and/or incompatible element types. This option should not be used for new code.

`-fms-extensions`

Accept some non-standard constructs used in Microsoft header files.

In C++ code, this allows member names in structures to be similar to previous types declarations.

```
typedef int UOW;
struct ABC {
  UOW UOW;
};
```

Some cases of unnamed fields in structures and unions are only accepted with this option. See Section 6.2.6 [Unnamed struct/union fields within structs/unions], page 612, for details.

Note that this option is off for all targets except for x86 targets using ms-abi.

`-fpermitted-flt-eval-methods=`*`style`*

ISO/IEC TS 18661-3 defines new permissible values for `FLT_EVAL_METHOD` that indicate that operations and constants with a semantic type that is an interchange or extended format should be evaluated to the precision and range of that type. These new values are a superset of those permitted under C99/C11, which does not specify the meaning of other positive values of `FLT_EVAL_METHOD`. As such, code conforming to C11 may not have been written expecting the possibility of the new values.

`-fpermitted-flt-eval-methods` specifies whether the compiler should allow only the values of `FLT_EVAL_METHOD` specified in C99/C11, or the extended set of values specified in ISO/IEC TS 18661-3.

style is either `c11` or `ts-18661-3` as appropriate.

The default when in a standards compliant mode (`-std=c11` or similar) is `-fpermitted-flt-eval-methods=c11`. The default when in a GNU dialect (`-std=gnu11` or similar) is `-fpermitted-flt-eval-methods=ts-18661-3`.

The '`-fdeps-*`' options are used to extract structured dependency information for a source. This involves determining what resources provided by other source files will be required to compile the source as well as what resources are provided by the source. This information can be used to add required dependencies between compilation rules of dependent sources based on their contents rather than requiring such information be reflected within the build tools as well.

`-fdeps-file=`*`file`*
: Where to write structured dependency information.

`-fdeps-format=`*`format`*
: The format to use for structured dependency information. '`p1689r5`' is the only supported format right now. Note that when this argument is specified, the output of '`-MF`' is stripped of some information (namely C++ modules) so that it does not use extended makefile syntax not understood by most tools.

`-fdeps-target=`*`file`*
: Analogous to `-MT` but for structured dependency information. This indicates the target which will ultimately need any required resources and provide any resources extracted from the source that may be required by other sources.

`-fplan9-extensions`
: Accept some non-standard constructs used in Plan 9 code.

This enables `-fms-extensions`, permits passing pointers to structures with anonymous fields to functions that expect pointers to elements of the type of the field, and permits referring to anonymous fields declared using a typedef. See Section 6.2.6 [Unnamed struct/union fields within structs/unions], page 612, for details. This is only supported for C, not C++.

`-fsigned-bitfields`
`-funsigned-bitfields`
`-fno-signed-bitfields`
`-fno-unsigned-bitfields`
: These options control whether a bit-field is signed or unsigned, when the declaration does not use either `signed` or `unsigned`. By default, such a bit-field is signed, because this is consistent: the basic integer types such as `int` are signed types.

`-fsigned-char`
: Let the type `char` be signed, like `signed char`.

Note that this is equivalent to `-fno-unsigned-char`, which is the negative form of `-funsigned-char`. Likewise, the option `-fno-signed-char` is equivalent to `-funsigned-char`.

`-funsigned-char`
: Let the type `char` be unsigned, like `unsigned char`.

Each kind of machine has a default for what `char` should be. It is either like `unsigned char` by default or like `signed char` by default.

Ideally, a portable program should always use `signed char` or `unsigned char` when it depends on the signedness of an object. But many programs have been written to use plain `char` and expect it to be signed, or expect it to be unsigned, depending on the machines they were written for. This option, and its inverse, let you make such a program work with the opposite default.

The type `char` is always a distinct type from each of `signed char` or `unsigned char`, even though its behavior is always just like one of those two.

`-fstrict-flex-arrays` (C and C++ only)
`-fstrict-flex-arrays=`*level* (C and C++ only)

Control when to treat the trailing array of a structure as a flexible array member for the purpose of accessing the elements of such an array. The value of *level* controls the level of strictness.

`-fstrict-flex-arrays` is equivalent to `-fstrict-flex-arrays=3`, which is the strictest; a trailing array is treated as a flexible array member only when it is declared as a flexible array member per C99 standard onwards.

The negative form `-fno-strict-flex-arrays` is equivalent to `-fstrict-flex-arrays=0`, which is the least strict. In this case all trailing arrays of structures are treated as flexible array members.

There are two more levels in between 0 and 3, which are provided to support older code that uses the GCC zero-length array extension ('`[0]`') or one-element array as flexible array members ('`[1]`'). When *level* is 1, the trailing array is treated as a flexible array member when it is declared as either '`[]`', '`[0]`', or '`[1]`'. When *level* is 2, the trailing array is treated as a flexible array member when it is declared as either '`[]`', or '`[0]`'.

You can control this behavior for a specific trailing array field of a structure by using the variable attribute `strict_flex_array` attribute (see Section 6.4.2 [Variable Attributes], page 699).

The `-fstrict_flex_arrays` option interacts with the `-Wstrict-flex-arrays` option. See Section 3.9 [Warning Options], page 100, for more information.

`-fsso-struct=`*endianness*

Set the default scalar storage order of structures and unions to the specified endianness. The accepted values are '`big-endian`', '`little-endian`' and '`native`' for the native endianness of the target (the default). This option is not supported for C++.

Warning: the `-fsso-struct` switch causes GCC to generate code that is not binary compatible with code generated without it if the specified endianness is not the native endianness of the target.

3.5 Options Controlling C++ Dialect

This section describes the command-line options that are only meaningful for C++ programs. You can also use most of the GNU compiler options regardless of what language your program is in. For example, you might compile a file `firstClass.C` like this:

```
g++ -g -fstrict-enums -O -c firstClass.C
```

In this example, only `-fstrict-enums` is an option meant only for C++ programs; you can use the other options with any language supported by GCC.

Some options for compiling C programs, such as `-std`, are also relevant for C++ programs. See Section 3.4 [Options Controlling C Dialect], page 45.

Here is a list of options that are *only* for compiling C++ programs:

`--compile-std-module`
: Build the compiled module interfaces (see Section 3.24 [C++ Modules], page 584) for the '`<bits/stdc++.h>`' header unit and the '`std`' and '`std.compat`' modules before compiling any source files explicitly specified on the command line. This is intended to be useful for building simple programs that use '`import std;`' with a single command.

`-fabi-version=`*n*
: Use version *n* of the C++ ABI. The default is version 0.

Version 0 refers to the version conforming most closely to the C++ ABI specification. Therefore, the ABI obtained using version 0 will change in different versions of G++ as ABI bugs are fixed.

Version 1 is the version of the C++ ABI that first appeared in G++ 3.2.

Version 2 is the version of the C++ ABI that first appeared in G++ 3.4, and was the default through G++ 4.9.

Version 3 corrects an error in mangling a constant address as a template argument.

Version 4, which first appeared in G++ 4.5, implements a standard mangling for vector types.

Version 5, which first appeared in G++ 4.6, corrects the mangling of attribute const/volatile on function pointer types, decltype of a plain decl, and use of a function parameter in the declaration of another parameter.

Version 6, which first appeared in G++ 4.7, corrects the promotion behavior of C++11 scoped enums and the mangling of template argument packs, const/static_cast, prefix ++ and –, and a class scope function used as a template argument.

Version 7, which first appeared in G++ 4.8, that treats nullptr_t as a builtin type and corrects the mangling of lambdas in default argument scope.

Version 8, which first appeared in G++ 4.9, corrects the substitution behavior of function types with function-cv-qualifiers.

Version 9, which first appeared in G++ 5.2, corrects the alignment of `nullptr_t`.

Version 10, which first appeared in G++ 6.1, adds mangling of attributes that affect type identity, such as ia32 calling convention attributes (e.g. '`stdcall`').

Version 11, which first appeared in G++ 7, corrects the mangling of sizeof... expressions and operator names. For multiple entities with the same name within a function, that are declared in different scopes, the mangling now changes starting with the twelfth occurrence. It also implies `-fnew-inheriting-ctors`.

Version 12, which first appeared in G++ 8, corrects the calling conventions for empty classes on the x86_64 target and for classes with only deleted copy/move constructors. It accidentally changes the calling convention for classes with a deleted copy constructor and a trivial move constructor.

Version 13, which first appeared in G++ 8.2, fixes the accidental change in version 12.

Version 14, which first appeared in G++ 10, corrects the mangling of the nullptr expression.

Version 15, which first appeared in G++ 10.3, corrects G++ 10 ABI tag regression.

Version 16, which first appeared in G++ 11, changes the mangling of `__alignof__` to be distinct from that of `alignof`, and dependent operator names.

Version 17, which first appeared in G++ 12, fixes layout of classes that inherit from aggregate classes with default member initializers in C++14 and up.

Version 18, which first appeared in G++ 13, fixes manglings of lambdas that have additional context.

Version 19, which first appeared in G++ 14, fixes manglings of structured bindings to include ABI tags, handling of cv-qualified [[no_unique_address]] members, and adds mangling of C++20 constraints on function templates.

Version 20, which first appeared in G++ 15, fixes manglings of lambdas in static data member initializers.

Version 21, which first appeared in G++ 16, fixes unnecessary captures in noexcept lambdas (c++/119764), layout of a base class with all explicitly defaulted constructors (c++/120012), and mangling of class and array objects with implicitly zero-initialized non-trailing subobjects (c++/121231).

See also `-Wabi`.

`-fabi-compat-version=`*n*
: On targets that support strong aliases, G++ works around mangling changes by creating an alias with the correct mangled name when defining a symbol with an incorrect mangled name. This switch specifies which ABI version to use for the alias.

With `-fabi-version=0` (the default), this defaults to 13 (GCC 8.2 compatibility). If another ABI version is explicitly selected, this defaults to 0. For compatibility with GCC versions 3.2 through 4.9, use `-fabi-compat-version=2`.

If this option is not provided but `-Wabi=`*n* is, that version is used for compatibility aliases. If this option is provided along with `-Wabi` (without the version), the version from this option is used for the warning.

`-fno-access-control`
: Turn off all access checking. This switch is mainly useful for working around bugs in the access control code.

`-faligned-new`
`-faligned-new=`*alignment*
: Enable support for C++17 `new` of types that require more alignment than `void* ::operator new(std::size_t)` provides. A numeric argument such as `-faligned-new=32` can be used to specify how much alignment (in bytes) is provided by that function, but few users will need to override the default of `alignof(std::max_align_t)`.

This flag is enabled by default for `-std=c++17`.

-fno-assume-sane-operators-new

The C++ standard allows replacing the global new, new[], delete and delete[] operators, though a lot of C++ programs don't replace them and just use the implementation provided version. Furthermore, the C++ standard allows omitting those calls if they are made from new or delete expressions (and by extension the same is assumed if __builtin_operator_new or __builtin_operator_delete functions are used). This option allows control over some optimizations around calls to those operators. With -fassume-sane-operators-new-delete option GCC may assume that calls to the replaceable global operators from new or delete expressions or from __builtin_operator_new or __builtin_operator_delete calls don't read or modify any global variables or variables whose address could escape to the operators (global state; except for errno for the new and new[] operators). This allows most optimizations across those calls and is something that the implementation provided operators satisfy unless malloc implementation details are observable in the code or unless malloc hooks are used, but might not be satisfied if a program replaces those operators. This behavior is enabled by default. With -fno-assume-sane-operators-new-delete option GCC must assume all these calls (whether from new or delete expressions or called directly) may read and write global state unless proven otherwise (e.g. when GCC compiles their implementation). Use this option if those operators are or may be replaced and code needs to expect such behavior.

-fchar8_t

-fno-char8_t

Enable support for char8_t as adopted for C++20. This includes the addition of a new char8_t fundamental type, changes to the types of UTF-8 string and character literals, new signatures for user-defined literals, associated standard library updates, and new __cpp_char8_t and __cpp_lib_char8_t feature test macros.

This option enables functions to be overloaded for ordinary and UTF-8 strings:

```
int f(const char *);    // #1
int f(const char8_t *); // #2
int v1 = f("text");     // Calls #1
int v2 = f(u8"text");   // Calls #2
```

and introduces new signatures for user-defined literals:

```
int operator""_udl1(char8_t);
int v3 = u8'x'_udl1;
int operator""_udl2(const char8_t*, std::size_t);
int v4 = u8"text"_udl2;
template<typename T, T...> int operator""_udl3();
int v5 = u8"text"_udl3;
```

The change to the types of UTF-8 string and character literals introduces incompatibilities with ISO C++11 and later standards. For example, the following code is well-formed under ISO C++11, but is ill-formed when -fchar8_t is specified.

```
const char *cp = u8"xx";// error: invalid conversion from
                        //        `const char8_t*' to `const char*'
int f(const char*);
auto v = f(u8"xx");     // error: invalid conversion from
```

```
                            //        `const char8_t*' to `const char*'
std::string s{u8"xx"};      // error: no matching function for call to
                            //        `std::basic_string<char>::basic_string()'
using namespace std::literals;
s = u8"xx"s;                // error: conversion from
                            //        `basic_string<char8_t>' to non-scalar
                            //        type `basic_string<char>' requested
```

`-fcheck-new`

Check that the pointer returned by `operator new` is non-null before attempting to modify the storage allocated. This check is normally unnecessary because the C++ standard specifies that `operator new` only returns `0` if it is declared `throw()`, in which case the compiler always checks the return value even without this option. In all other cases, when `operator new` has a non-empty exception specification, memory exhaustion is signalled by throwing `std::bad_alloc`. See also '`new (nothrow)`'.

`-fconcepts`

Enable support for the C++ Concepts feature for constraining template arguments. With `-std=c++20` and above, Concepts are part of the language standard, so `-fconcepts` defaults to on.

Some constructs that were allowed by the earlier C++ Extensions for Concepts Technical Specification, ISO 19217 (2015), but didn't make it into the standard, could additionally be enabled by `-fconcepts-ts`. The option `-fconcepts-ts` was deprecated in GCC 14 and removed in GCC 15; users are expected to convert their code to C++20 concepts.

`-fconcepts-diagnostics-depth=`*n*

Specify maximum error replay depth during recursive diagnosis of a constraint satisfaction failure. The default is 1.

`-fconstexpr-depth=`*n*

Set the maximum nested evaluation depth for C++11 constexpr functions to *n*. A limit is needed to detect endless recursion during constant expression evaluation. The minimum specified by the standard is 512.

`-fconstexpr-cache-depth=`*n*

Set the maximum level of nested evaluation depth for C++11 constexpr functions that will be cached to *n*. This is a heuristic that trades off compilation speed (when the cache avoids repeated calculations) against memory consumption (when the cache grows very large from highly recursive evaluations). The default is 8. Very few users are likely to want to adjust it, but if your code does heavy constexpr calculations you might want to experiment to find which value works best for you.

`-fconstexpr-fp-except`

Annex F of the C standard specifies that IEC559 floating point exceptions encountered at compile time should not stop compilation. C++ compilers have historically not followed this guidance, instead treating floating point division by zero as non-constant even though it has a well defined value. This flag tells the compiler to give Annex F priority over other rules saying that a particular operation is undefined.

```
constexpr float inf = 1./0.; // OK with -fconstexpr-fp-except
```

`-fconstexpr-loop-limit=`*n*

Set the maximum number of iterations for a loop in C++14 constexpr functions to *n*. A limit is needed to detect infinite loops during constant expression evaluation. The default is 262144 (1<<18).

`-fconstexpr-ops-limit=`*n*

Set the maximum number of operations during a single constexpr evaluation. Even when number of iterations of a single loop is limited with the above limit, if there are several nested loops and each of them has many iterations but still smaller than the above limit, or if in a body of some loop or even outside of a loop too many expressions need to be evaluated, the resulting constexpr evaluation might take too long. The default is 33554432 (1<<25).

`-fcontracts`

Enable experimental support for the C++ Contracts feature, as briefly added to and then removed from the C++20 working paper (N4820). The implementation also includes proposed enhancements from papers P1290, P1332, and P1429. This functionality is intended mostly for those interested in experimentation towards refining the feature to get it into shape for a future C++ standard.

On violation of a checked contract, the violation handler is called. Users can replace the violation handler by defining

```
void
handle_contract_violation (const std::experimental::contract_violation&);
```

There are different sets of additional flags that can be used together to specify which contracts will be checked and how, for N4820 contracts, P1332 contracts, or P1429 contracts; these sets cannot be used together.

`-fcontract-mode=`[`on`|`off`]

Control whether any contracts have any semantics at all. Defaults to on.

`-fcontract-assumption-mode=`[`on`|`off`]

[N4820] Control whether contracts with level '`axiom`' should have the assume semantic. Defaults to on.

`-fcontract-build-level=`[`off`|`default`|`audit`]

[N4820] Specify which level of contracts to generate checks for. Defaults to '`default`'.

`-fcontract-continuation-mode=`[`on`|`off`]

[N4820] Control whether to allow the program to continue executing after a contract violation. That is, do checked contracts have the '`maybe`' semantic described below rather than the '`never`' semantic. Defaults to off.

`-fcontract-role=`*name*`:`*default*`,`*audit*`,`*axiom*

[P1332] Specify the concrete semantics for each contract level of a particular contract role.

`-fcontract-semantic=[default|audit|axiom]:`*semantic*
: [P1429] Specify the concrete semantic for a particular contract level.

`-fcontract-strict-declarations=[on|off]`
: Control whether to reject adding contracts to a function after its first declaration. Defaults to off.

The possible concrete semantics for that can be specified with '`-fcontract-role`' or '`-fcontract-semantic`' are:

`ignore` This contract has no effect.

`assume` This contract is treated like C++23 `[[assume]]`.

`check_never_continue`
`never`
`abort` This contract is checked. If it fails, the violation handler is called. If the handler returns, `std::terminate` is called.

`check_maybe_continue`
`maybe` This contract is checked. If it fails, the violation handler is called. If the handler returns, execution continues normally.

`-fcoroutines`
: Enable support for the C++ coroutines extension. With `-std=c++20` and above, coroutines are part of the language standard, so `-fcoroutines` defaults to on.

`-fdiagnostics-all-candidates`
: Permit the C++ front end to note all candidates during overload resolution failure, including when a deleted function is selected.

`-fdump-lang-`
`-fdump-lang-`*switch*
`-fdump-lang-`*switch*`-`*options*
`-fdump-lang-`*switch*`-`*options*`=`*filename*
: Control the dumping of C++-specific information. The *options* and *filename* portions behave as described in the `-fdump-tree` option. The following *switch* values are accepted:

'`all`' Enable all of the below.

'`class`' Dump class hierarchy information. Virtual table information is emitted unless '`slim`' is specified.

'`module`' Dump module information. Options `lineno` (locations), `graph` (reachability), `blocks` (clusters), `uid` (serialization), `alias` (mergeable), `asmname` (Elrond), `eh` (mapper) & `vops` (macros) may provide additional information.

'`raw`' Dump the raw internal tree data.

'`tinst`' Dump the sequence of template instantiations, indented to show the depth of recursion. The `lineno` option adds the source location where the instantiation was triggered, and the `details` option also dumps pre-instantiation substitutions such as those performed during template argument deduction.

Lines in the .tinst dump start with 'I' for an instantiation, 'S' for another substitution, and 'R[IS]' for the reopened context of a deferred instantiation.

-fno-elide-constructors
: The C++ standard allows an implementation to omit creating a temporary that is only used to initialize another object of the same type. Specifying this option disables that optimization, and forces G++ to call the copy constructor in all cases. This option also causes G++ to call trivial member functions which otherwise would be expanded inline.

  In C++17, the compiler is required to omit these temporaries, but this option still affects trivial member functions.

-fno-enforce-eh-specs
: Don't generate code to check for violation of exception specifications at run time. This option violates the C++ standard, but may be useful for reducing code size in production builds, much like defining NDEBUG. This does not give user code permission to throw exceptions in violation of the exception specifications; the compiler still optimizes based on the specifications, so throwing an unexpected exception results in undefined behavior at run time.

-fextern-tls-init
-fno-extern-tls-init
: The C++11 and OpenMP standards allow thread_local and threadprivate variables to have dynamic (runtime) initialization. To support this, any use of such a variable goes through a wrapper function that performs any necessary initialization. When the use and definition of the variable are in the same translation unit, this overhead can be optimized away, but when the use is in a different translation unit there is significant overhead even if the variable doesn't actually need dynamic initialization. If the programmer can be sure that no use of the variable in a non-defining TU needs to trigger dynamic initialization (either because the variable is statically initialized, or a use of the variable in the defining TU will be executed before any uses in another TU), they can avoid this overhead with the -fno-extern-tls-init option.

  On targets that support symbol aliases, the default is -fextern-tls-init. On targets that do not support symbol aliases, the default is -fno-extern-tls-init.

-ffold-simple-inlines
-fno-fold-simple-inlines
: Permit the C++ frontend to fold calls to std::move, std::forward, std::addressof, std::to_underlying and std::as_const. In contrast to inlining, this means no debug information will be generated for such calls. Since these functions are rarely interesting to debug, this flag is enabled by default unless -fno-inline is active.

`-fno-gnu-keywords`

Do not recognize `typeof` as a keyword, so that code can use this word as an identifier. You can use the keyword `__typeof__` instead. This option is implied by the strict ISO C++ dialects: `-ansi`, `-std=c++98`, `-std=c++11`, etc.

`-fno-immediate-escalation`

Do not enable immediate function escalation whereby certain functions can be promoted to consteval, as specified in P2564R3. For example:

```
consteval int id(int i) { return i; }

constexpr int f(auto t)
{
  return t + id(t); // id causes f<int> to be promoted to consteval
}

void g(int i)
{
  f (3);
}
```

compiles in C++20: `f` is an immediate-escalating function (due to the `auto` it is a function template and is declared `constexpr`) and `id(t)` is an immediate-escalating expression, so `f` is promoted to `consteval`. Consequently, the call to `id(t)` is in an immediate context, so doesn't have to produce a constant (that is the mechanism allowing consteval function composition). However, with `-fno-immediate-escalation`, `f` is not promoted to `consteval`, and since the call to consteval function `id(t)` is not a constant expression, the compiler rejects the code.

This option is turned on by default; it is only effective in C++20 mode or later.

`-fimplicit-constexpr`

Make inline functions implicitly constexpr, if they satisfy the requirements for a constexpr function. This option can be used in C++14 mode or later. This can result in initialization changing from dynamic to static and other optimizations.

`-fno-implicit-templates`

Never emit code for non-inline templates that are instantiated implicitly (i.e. by use); only emit code for explicit instantiations. If you use this option, you must take care to structure your code to include all the necessary explicit instantiations to avoid getting undefined symbols at link time. See Section 8.5 [Template Instantiation], page 1064, for more information.

`-fno-implicit-inline-templates`

Don't emit code for implicit instantiations of inline templates, either. The default is to handle inlines differently so that compiles with and without optimization need the same set of explicit instantiations.

`-fno-implement-inlines`

To save space, do not emit out-of-line copies of inline functions controlled by `#pragma implementation`. This causes linker errors if these functions are not inlined everywhere they are called.

`-fmodules`
`-fno-modules`
: Enable support for C++20 modules (see Section 3.24 [C++ Modules], page 584). The `-fno-modules` is usually not needed, as that is the default. Even though this is a C++20 feature, it is not currently implicitly enabled by selecting that standard version.

`-fmodule-header`
`-fmodule-header=user`
`-fmodule-header=system`
: Compile a header file to create an importable header unit.

`-fmodule-implicit-inline`
: Member functions defined in their class definitions are not implicitly inline for modular code. This is different to traditional C++ behavior, for good reasons. However, it may result in a difficulty during code porting. This option makes such function definitions implicitly inline. It does however generate an ABI incompatibility, so you must use it everywhere or nowhere. (Such definitions outside of a named module remain implicitly inline, regardless.)

`-fno-module-lazy`
: Disable lazy module importing and module mapper creation.

`-fmodule-mapper=[hostname]:port[?ident]`
`-fmodule-mapper=|program[?ident] args...`
`-fmodule-mapper==socket[?ident]`
`-fmodule-mapper=<>[inout][?ident]`
`-fmodule-mapper=<in>out[?ident]`
`-fmodule-mapper=file[?ident]`
: An oracle to query for module name to filename mappings. If unspecified the `CXX_MODULE_MAPPER` environment variable is used, and if that is unset, an in-process default is provided.

`-fmodule-only`
: Only emit the Compiled Module Interface, inhibiting any object file.

`-fms-extensions`
: Disable Wpedantic warnings about constructs used in MFC, such as implicit int and getting a pointer to member function via non-standard syntax.

`-fnew-inheriting-ctors`
: Enable the P0136 adjustment to the semantics of C++11 constructor inheritance. This is part of C++17 but also considered to be a Defect Report against C++11 and C++14. This flag is enabled by default unless `-fabi-version=10` or lower is specified.

`-fnew-ttp-matching`
: Enable the P0522 resolution to Core issue 150, template template parameters and default arguments: this allows a template with default template arguments as an argument for a template template parameter with fewer template parameters. This flag is enabled by default for `-std=c++17`.

`-fno-nonansi-builtins`
: Disable built-in declarations of functions that are not mandated by ANSI/ISO C. These include `ffs`, `alloca`, `_exit`, `index`, `bzero`, `conjf`, and other related functions.

`-fnothrow-opt`
: Treat a `throw()` exception specification as if it were a `noexcept` specification to reduce or eliminate the text size overhead relative to a function with no exception specification. If the function has local variables of types with non-trivial destructors, the exception specification actually makes the function smaller because the EH cleanups for those variables can be optimized away. The semantic effect is that an exception thrown out of a function with such an exception specification results in a call to `terminate` rather than `unexpected`.

`-fno-operator-names`
: Do not treat the operator name keywords `and`, `bitand`, `bitor`, `compl`, `not`, `or` and `xor` as synonyms as keywords.

`-fno-optional-diags`
: Disable diagnostics that the standard says a compiler does not need to issue. Currently, the only such diagnostic issued by G++ is the one for a name having multiple meanings within a class.

`-fno-pretty-templates`
: When an error message refers to a specialization of a function template, the compiler normally prints the signature of the template followed by the template arguments and any typedefs or typenames in the signature (e.g. `void f(T) [with T = int]` rather than `void f(int)`) so that it's clear which template is involved. When an error message refers to a specialization of a class template, the compiler omits any template arguments that match the default template arguments for that template. If either of these behaviors make it harder to understand the error message rather than easier, you can use `-fno-pretty-templates` to disable them.

`-frange-for-ext-temps`
: Enable lifetime extension of C++ range based for temporaries. With `-std=c++23` and above this is part of the language standard, so lifetime of the temporaries is extended until the end of the loop by default. This option allows enabling that behavior also in earlier versions of the standard.

`-fno-rtti`
: Disable generation of information about every class with virtual functions for use by the C++ run-time type identification features (`dynamic_cast` and `typeid`). If you don't use those parts of the language, you can save some space by using this flag. Note that exception handling uses the same information, but G++ generates it as needed. The `dynamic_cast` operator can still be used for casts that do not require run-time type information, i.e. casts to `void *` or to unambiguous base classes.

  Mixing code compiled with `-frtti` with that compiled with `-fno-rtti` may not work. For example, programs may fail to link if a class compiled with `-fno-rtti` is used as a base for a class compiled with `-frtti`.

`-fsized-deallocation`
Enable the built-in global declarations

```
void operator delete (void *, std::size_t) noexcept;
void operator delete[] (void *, std::size_t) noexcept;
```

as introduced in C++14. This is useful for user-defined replacement deallocation functions that, for example, use the size of the object to make deallocation faster. Enabled by default under `-std=c++14` and above. The flag `-Wsized-deallocation` warns about places that might want to add a definition.

`-fstrict-enums`
Allow the compiler to optimize using the assumption that a value of enumerated type can only be one of the values of the enumeration (as defined in the C++ standard; basically, a value that can be represented in the minimum number of bits needed to represent all the enumerators). This assumption may not be valid if the program uses a cast to convert an arbitrary integer value to the enumerated type. This option has no effect for an enumeration type with a fixed underlying type.

`-fstrong-eval-order`
`-fstrong-eval-order=kind`
Evaluate member access, array subscripting, and shift expressions in left-to-right order, and evaluate assignment in right-to-left order, as adopted for C++17. `-fstrong-eval-order` is equivalent to `-fstrong-eval-order=all`, and is enabled by default with `-std=c++17` or later.

`-fstrong-eval-order=some` enables just the ordering of member access and shift expressions, and is the default for C++ dialects prior to C++17.

`-fstrong-eval-order=none` is equivalent to `-fno-strong-eval-order`.

`-ftemplate-backtrace-limit=n`
Set the maximum number of template instantiation notes for a single warning or error to *n*. The default value is 10.

`-ftemplate-depth=n`
Set the maximum instantiation depth for template classes to *n*. A limit on the template instantiation depth is needed to detect endless recursions during template class instantiation. ANSI/ISO C++ conforming programs must not rely on a maximum depth greater than 17 (changed to 1024 in C++11). The default value is 900, as the compiler can run out of stack space before hitting 1024 in some situations.

`-fno-threadsafe-statics`
Do not emit the extra code to use the routines specified in the C++ ABI for thread-safe initialization of local statics. You can use this option to reduce code size slightly in code that doesn't need to be thread-safe.

`-fuse-cxa-atexit`
Register destructors for objects with static storage duration with the `__cxa_atexit` function rather than the `atexit` function. This option is required for fully standards-compliant handling of static destructors, but only works if your C library supports `__cxa_atexit`.

`-fno-use-cxa-get-exception-ptr`
: Don't use the `__cxa_get_exception_ptr` runtime routine. This causes `std::uncaught_exception` to be incorrect, but is necessary if the runtime routine is not available.

`-fvisibility-inlines-hidden`
: This switch declares that the user does not attempt to compare pointers to inline functions or methods where the addresses of the two functions are taken in different shared objects.

The effect of this is that GCC may, effectively, mark inline methods with `__attribute__ ((visibility ("hidden")))` so that they do not appear in the export table of a DSO and do not require a PLT indirection when used within the DSO. Enabling this option can have a dramatic effect on load and link times of a DSO as it massively reduces the size of the dynamic export table when the library makes heavy use of templates.

The behavior of this switch is not quite the same as marking the methods as hidden directly, because it does not affect static variables local to the function or cause the compiler to deduce that the function is defined in only one shared object.

You may mark a method as having a visibility explicitly to negate the effect of the switch for that method. For example, if you do want to compare pointers to a particular inline method, you might mark it as having default visibility. Marking the enclosing class with explicit visibility has no effect.

Explicitly instantiated inline methods are unaffected by this option as their linkage might otherwise cross a shared library boundary. See Section 8.5 [Template Instantiation], page 1064.

`-fvisibility-ms-compat`
: This flag attempts to use visibility settings to make GCC's C++ linkage model compatible with that of Microsoft Visual Studio.

The flag makes these changes to GCC's linkage model:

1. It sets the default visibility to `hidden`, like `-fvisibility=hidden`.
2. Types, but not their members, are not hidden by default.
3. The One Definition Rule is relaxed for types without explicit visibility specifications that are defined in more than one shared object: those declarations are permitted if they are permitted when this option is not used.

In new code it is better to use `-fvisibility=hidden` and export those classes that are intended to be externally visible. Unfortunately it is possible for code to rely, perhaps accidentally, on the Visual Studio behavior.

Among the consequences of these changes are that static data members of the same type with the same name but defined in different shared objects are different, so changing one does not change the other; and that pointers to function members defined in different shared objects may not compare equal. When this flag is given, it is a violation of the ODR to define types with the same name differently.

-fno-weak
: Do not use weak symbol support, even if it is provided by the linker. By default, G++ uses weak symbols if they are available. This option exists only for testing, and should not be used by end-users; it results in inferior code and has no benefits. This option may be removed in a future release of G++.

-fext-numeric-literals (C++ and Objective-C++ only)
: Accept imaginary, fixed-point, or machine-defined literal number suffixes as GNU extensions. When this option is turned off these suffixes are treated as C++11 user-defined literal numeric suffixes. This is on by default for all pre-C++11 dialects and all GNU dialects: -std=c++98, -std=gnu++98, -std=gnu++11, -std=gnu++14. This option is off by default for ISO C++11 onwards (-std=c++11, ...).

-nostdinc++
: Do not search for header files in the standard directories specific to C++, but do still search the other standard directories. (This option is used when building the C++ library.)

-flang-info-include-translate
-flang-info-include-translate-not
-flang-info-include-translate=*header*
: Inform of include translation events. The first will note accepted include translations, the second will note declined include translations. The *header* form will inform of include translations relating to that specific header. If *header* is of the form "user" or <system> it will be resolved to a specific user or system header using the include path.

-flang-info-module-cmi
-flang-info-module-cmi=*module*
: Inform of Compiled Module Interface pathnames. The first will note all read CMI pathnames. The *module* form will not reading a specific module's CMI. *module* may be a named module or a header-unit (the latter indicated by either being a pathname containing directory separators or enclosed in <> or "").

-stdlib=*libstdc++,libc++*
: When G++ is configured to support this option, it allows specification of alternate C++ runtime libraries. Two options are available: *libstdc++* (the default, native C++ runtime for G++) and *libc++* which is the C++ runtime installed on some operating systems (e.g. Darwin versions from Darwin11 onwards). The option switches G++ to use the headers from the specified library and to emit -lstdc++ or -lc++ respectively, when a C++ runtime is required for linking.

In addition, these warning options have meanings only for C++ programs:

-Wabi-tag (C++ and Objective-C++ only)
: Warn when a type with an ABI tag is used in a context that does not have that ABI tag. See Section 8.7 [C++ Attributes], page 1067, for more information about ABI tags.

`-Wno-abbreviated-auto-in-template-arg`

Disable the error for an `auto` placeholder type used within a template argument list to declare a C++20 abbreviated function template, e.g.

```
void f(S<auto>);
```

This feature was proposed in the Concepts TS, but was not adopted into C++20; in the standard, a placeholder in a parameter declaration must appear as a decl-specifier. The error can also be reduced to a warning by `-fpermissive` or `-Wno-error=abbreviated-auto-in-template-arg`.

`-Wcomma-subscript` (C++ and Objective-C++ only)

Warn about uses of a comma expression within a subscripting expression. This usage was deprecated in C++20 and is going to be removed in C++23. However, a comma expression wrapped in `( )` is not deprecated. Example:

```
void f(int *a, int b, int c) {
    a[b,c];     // deprecated in C++20, invalid in C++23
    a[(b,c)];   // OK
}
```

In C++23 it is valid to have comma separated expressions in a subscript when an overloaded subscript operator is found and supports the right number and types of arguments. G++ will accept the formerly valid syntax for code that is not valid in C++23 but used to be valid but deprecated in C++20 with a pedantic warning that can be disabled with `-Wno-comma-subscript`.

Enabled by default with `-std=c++20` unless `-Wno-deprecated`, and after `-std=c++23` regardless of `-Wno-deprecated`. Before `-std=c++20`, enabled with explicit `-Wdeprecated`.

This warning is upgraded to an error by `-pedantic-errors` in C++23 mode or later.

`-Wctad-maybe-unsupported` (C++ and Objective-C++ only)

Warn when performing class template argument deduction (CTAD) on a type with no explicitly written deduction guides. This warning will point out cases where CTAD succeeded only because the compiler synthesized the implicit deduction guides, which might not be what the programmer intended. Certain style guides allow CTAD only on types that specifically "opt-in"; i.e., on types that are designed to support CTAD. This warning can be suppressed with the following pattern:

```
struct allow_ctad_t; // any name works
template <typename T> struct S {
  S(T) { }
};
// Guide with incomplete parameter type will never be considered.
S(allow_ctad_t) -> S<void>;
```

`-Wctor-dtor-privacy` (C++ and Objective-C++ only)

Warn when a class seems unusable because all the constructors or destructors in that class are private, and it has neither friends nor public static member functions. Also warn if there are no non-private methods, and there's at least one private member function that isn't a constructor or destructor.

`-Wdangling-reference` (C++ and Objective-C++ only)

Warn when a reference is bound to a temporary whose lifetime has ended. For example:

```
int n = 1;
const int& r = std::max(n - 1, n + 1); // r is dangling
```

In the example above, two temporaries are created, one for each argument, and a reference to one of the temporaries is returned. However, both temporaries are destroyed at the end of the full expression, so the reference `r` is dangling.

This warning also detects dangling references in member initializer lists:

```
const int& f(const int& i) { return i; }
struct S {
  const int &r; // r is dangling
  S() : r(f(10)) { }
};
```

Member functions are checked as well, but only their object argument:

```
struct S {
   const S& self () { return *this; }
};
const S& s = S().self(); // s is dangling
```

Certain functions are safe in this respect, for example `std::use_facet`: they take and return a reference, but they don't return one of its arguments, which can fool the warning. Such functions can be excluded from the warning by wrapping them in a `#pragma`:

```
#pragma GCC diagnostic push
#pragma GCC diagnostic ignored "-Wdangling-reference"
const T& foo (const T&) { ... }
#pragma GCC diagnostic pop
```

The `#pragma` can also surround the class; in that case, the warning will be disabled for all the member functions.

`-Wdangling-reference` also warns about code like

```
auto p = std::minmax(1, 2);
```

where `std::minmax` returns `std::pair<const int&, const int&>`, and both references dangle after the end of the full expression that contains the call to `std::minmax`.

The warning does not warn for `std::span`-like classes. We consider classes of the form:

```
template<typename T>
struct Span {
  T* data_;
  std::size len_;
};
```

as `std::span`-like; that is, the class is a non-union class that has a pointer data member and a trivial destructor.

The warning can be disabled by using the `gnu::no_dangling` attribute (see Section 8.7 [C++ Attributes], page 1067).

This warning is enabled by `-Wextra`.

`-Wdelete-non-virtual-dtor` (C++ and Objective-C++ only)
: Warn when `delete` is used to destroy an instance of a class that has virtual functions and non-virtual destructor. It is unsafe to delete an instance of a derived class through a pointer to a base class if the base class does not have a virtual destructor. This warning is enabled by `-Wall`.

`-Wdeprecated-copy` (C++ and Objective-C++ only)
: Warn that the implicit declaration of a copy constructor or copy assignment operator is deprecated if the class has a user-provided copy constructor or copy assignment operator, in C++11 and up. This warning is enabled by `-Wextra`.

`-Wdeprecated-copy-dtor` (C++ and Objective-C++ only)
: Similar to `-Wdeprecated-copy`, but also deprecate if the class has a user-provided destructor.

`-Wno-deprecated-enum-enum-conversion` (C++ and Objective-C++ only)
: Disable the warning about the case when the usual arithmetic conversions are applied on operands where one is of enumeration type and the other is of a different enumeration type. This conversion was deprecated in C++20. For example:

```
enum E1 { e };
enum E2 { f };
int k = f - e;
```

`-Wdeprecated-enum-enum-conversion` is enabled by default with `-std=c++20`. In pre-C++20 dialects, this warning can be enabled by `-Wenum-conversion` or `-Wdeprecated`.

`-Wno-deprecated-enum-float-conversion` (C++ and Objective-C++ only)
: Disable the warning about the case when the usual arithmetic conversions are applied on operands where one is of enumeration type and the other is of a floating-point type. This conversion was deprecated in C++20. For example:

```
enum E1 { e };
enum E2 { f };
bool b = e <= 3.7;
```

`-Wdeprecated-enum-float-conversion` is enabled by default with `-std=c++20`. In pre-C++20 dialects, this warning can be enabled by `-Wenum-conversion` or `-Wdeprecated`.

`-Wdeprecated-literal-operator` (C++ and Objective-C++ only)
: Warn that the declaration of a user-defined literal operator with a space before the suffix is deprecated. This warning is enabled by default in C++23, or with explicit `-Wdeprecated`.

```
string operator "" _i18n(const char*, std::size_t); // deprecated
string operator ""_i18n(const char*, std::size_t); // preferred
```

`-Wdeprecated-variadic-comma-omission` (C++ and Objective-C++ only)
: Warn that omitting a comma before the varargs `...` at the end of a function parameter list is deprecated. This warning is enabled by default in C++26, or with explicit `-Wdeprecated`.

```
void f1(int...); // deprecated
void f1(int, ...); // preferred
```

```
template <typename ...T>
void f2(T...); // ok
template <typename ...T>
void f3(T......); // deprecated
```

`-Wno-elaborated-enum-base`

For C++11 and above, warn if an (invalid) additional enum-base is used in an elaborated-type-specifier. That is, if an enum with given underlying type and no enumerator list is used in a declaration other than just a standalone declaration of the enum. Enabled by default. This warning is upgraded to an error with -pedantic-errors.

`-Wno-init-list-lifetime` (C++ and Objective-C++ only)

Do not warn about uses of `std::initializer_list` that are likely to result in dangling pointers. Since the underlying array for an `initializer_list` is handled like a normal C++ temporary object, it is easy to inadvertently keep a pointer to the array past the end of the array's lifetime. For example:

- If a function returns a temporary `initializer_list`, or a local `initializer_list` variable, the array's lifetime ends at the end of the return statement, so the value returned has a dangling pointer.
- If a new-expression creates an `initializer_list`, the array only lives until the end of the enclosing full-expression, so the `initializer_list` in the heap has a dangling pointer.
- When an `initializer_list` variable is assigned from a brace-enclosed initializer list, the temporary array created for the right side of the assignment only lives until the end of the full-expression, so at the next statement the `initializer_list` variable has a dangling pointer.

```
// li's initial underlying array lives as long as li
std::initializer_list<int> li = { 1,2,3 };
// assignment changes li to point to a temporary array
li = { 4, 5 };
// now the temporary is gone and li has a dangling pointer
int i = li.begin()[0] // undefined behavior
```

- When a list constructor stores the `begin` pointer from the `initializer_list` argument, this doesn't extend the lifetime of the array, so if a class variable is constructed from a temporary `initializer_list`, the pointer is left dangling by the end of the variable declaration statement.

`-Winvalid-constexpr`

Warn when a function never produces a constant expression. In C++20 and earlier, for every `constexpr` function and function template, there must be at least one set of function arguments in at least one instantiation such that an invocation of the function or constructor could be an evaluated subexpression of a core constant expression. C++23 removed this restriction, so it's possible to have a function or a function template marked `constexpr` for which no invocation satisfies the requirements of a core constant expression.

This warning is enabled as a pedantic warning by default in C++20 and earlier. In C++23, `-Winvalid-constexpr` can be turned on, in which case it will be an ordinary warning. For example:

```
void f (int& i);
```

```
constexpr void
g (int& i)
{
  // Warns by default in C++20, in C++23 only with -Winvalid-constexpr.
  f(i);
}
```

`-Winvalid-imported-macros`
: Verify all imported macro definitions are valid at the end of compilation. This is not enabled by default, as it requires additional processing to determine. It may be useful when preparing sets of header-units to ensure consistent macros.

`-Wno-literal-suffix` (C++ and Objective-C++ only)
: Do not warn when a string or character literal is followed by a ud-suffix which does not begin with an underscore. As a conforming extension, GCC treats such suffixes as separate preprocessing tokens in order to maintain backwards compatibility with code that uses formatting macros from `<inttypes.h>`. For example:

```
#define __STDC_FORMAT_MACROS
#include <inttypes.h>
#include <stdio.h>

int main() {
  int64_t i64 = 123;
  printf("My int64: %" PRId64"\n", i64);
}
```

In this case, `PRId64` is treated as a separate preprocessing token.

This option also controls warnings when a user-defined literal operator is declared with a literal suffix identifier that doesn't begin with an underscore. Literal suffix identifiers that don't begin with an underscore are reserved for future standardization.

These warnings are enabled by default.

`-Wno-narrowing` (C++ and Objective-C++ only)
: For C++11 and later standards, narrowing conversions are diagnosed by default, as required by the standard. A narrowing conversion from a constant produces an error, and a narrowing conversion from a non-constant produces a warning, but `-Wno-narrowing` suppresses the diagnostic. Note that this does not affect the meaning of well-formed code; narrowing conversions are still considered ill-formed in SFINAE contexts.

With `-Wnarrowing` in C++98, warn when a narrowing conversion prohibited by C++11 occurs within '`{ }`', e.g.

```
int i = { 2.2 }; // error: narrowing from double to int
```

This flag is included in `-Wall` and `-Wc++11-compat`.

`-Wnoexcept` (C++ and Objective-C++ only)
: Warn when a noexcept-expression evaluates to false because of a call to a function that does not have a non-throwing exception specification (i.e. `throw()` or `noexcept`) but is known by the compiler to never throw an exception.

-Wnoexcept-type (C++ and Objective-C++ only)
: Warn if the C++17 feature making noexcept part of a function type changes the mangled name of a symbol relative to C++14. Enabled by -Wabi and -Wc++17-compat.

As an example:

```
template <class T> void f(T t) { t(); };
void g() noexcept;
void h() { f(g); }
```

In C++14, f calls f<void(*)()>, but in C++17 it calls f<void(*)()noexcept>.

-Wclass-memaccess (C++ and Objective-C++ only)
: Warn when the destination of a call to a raw memory function such as memset or memcpy is an object of class type, and when writing into such an object might bypass the class non-trivial or deleted constructor or copy assignment, violate const-correctness or encapsulation, or corrupt virtual table pointers. Modifying the representation of such objects may violate invariants maintained by member functions of the class. For example, the call to memset below is undefined because it modifies a non-trivial class object and is, therefore, diagnosed. The safe way to either initialize or clear the storage of objects of such types is by using the appropriate constructor or assignment operator, if one is available.

```
std::string str = "abc";
memset (&str, 0, sizeof str);
```

The -Wclass-memaccess option is enabled by -Wall. Explicitly casting the pointer to the class object to void * or to a type that can be safely accessed by the raw memory function suppresses the warning.

-Wnon-virtual-dtor (C++ and Objective-C++ only)
: Warn when a class has virtual functions and an accessible non-virtual destructor itself or in an accessible polymorphic base class, in which case it is possible but unsafe to delete an instance of a derived class through a pointer to the class itself or base class. This warning is automatically enabled if -Weffc++ is specified. The -Wdelete-non-virtual-dtor option (enabled by -Wall) should be preferred because it warns about the unsafe cases without false positives.

-Wregister (C++ and Objective-C++ only)
: Warn on uses of the register storage class specifier, except when it is part of the GNU Section 6.11.6 [Explicit Register Variables], page 807, extension. The use of the register keyword as storage class specifier has been deprecated in C++11 and removed in C++17. Enabled by default with -std=c++17.

-Wreorder (C++ and Objective-C++ only)
: Warn when the order of member initializers given in the code does not match the order in which they must be executed. For instance:

```
struct A {
  int i;
  int j;
  A(): j (0), i (1) { }
};
```

The compiler rearranges the member initializers for `i` and `j` to match the declaration order of the members, emitting a warning to that effect. This warning is enabled by `-Wall`.

`-Wno-pessimizing-move` (C++ and Objective-C++ only)
This warning warns when a call to `std::move` prevents copy elision. A typical scenario when copy elision can occur is when returning in a function with a class return type, when the expression being returned is the name of a non-volatile automatic object, and is not a function parameter, and has the same type as the function return type.

```
struct T {
...
};
T fn()
{
  T t;
  ...
  return std::move (t);
}
```

But in this example, the `std::move` call prevents copy elision.

This warning is enabled by `-Wall`.

`-Wno-redundant-move` (C++ and Objective-C++ only)
This warning warns about redundant calls to `std::move`; that is, when a move operation would have been performed even without the `std::move` call. This happens because the compiler is forced to treat the object as if it were an rvalue in certain situations such as returning a local variable, where copy elision isn't applicable. Consider:

```
struct T {
...
};
T fn(T t)
{
  ...
  return std::move (t);
}
```

Here, the `std::move` call is redundant. Because G++ implements Core Issue 1579, another example is:

```
struct T { // convertible to U
...
};
struct U {
...
};
U fn()
{
  T t;
  ...
  return std::move (t);
}
```

In this example, copy elision isn't applicable because the type of the expression being returned and the function return type differ, yet G++ treats the return value as if it were designated by an rvalue.

This warning is enabled by `-Wextra`.

`-Wrange-loop-construct` (C++ and Objective-C++ only)
: This warning warns when a C++ range-based for-loop is creating an unnecessary copy. This can happen when the range declaration is not a reference, but probably should be. For example:

```
struct S { char arr[128]; };
void fn () {
  S arr[5];
  for (const auto x : arr) { ... }
}
```

It does not warn when the type being copied is a trivially-copyable type whose size is less than 64 bytes.

This warning also warns when a loop variable in a range-based for-loop is initialized with a value of a different type resulting in a copy. For example:

```
void fn() {
  int arr[10];
  for (const double &x : arr) { ... }
}
```

In the example above, in every iteration of the loop a temporary value of type `double` is created and destroyed, to which the reference `const double &` is bound.

This warning is enabled by `-Wall`.

`-Wredundant-tags` (C++ and Objective-C++ only)
: Warn about redundant class-key and enum-key in references to class types and enumerated types in contexts where the key can be eliminated without causing an ambiguity. For example:

```
struct foo;
struct foo *p;   // warn that keyword struct can be eliminated
```

On the other hand, in this example there is no warning:

```
struct foo;
void foo ();   // "hides" struct foo
void bar (struct foo&);  // no warning, keyword struct is necessary
```

`-Wno-subobject-linkage` (C++ and Objective-C++ only)
: Do not warn if a class type has a base or a field whose type uses the anonymous namespace or depends on a type with no linkage. If a type A depends on a type B with no or internal linkage, defining it in multiple translation units would be an ODR violation because the meaning of B is different in each translation unit. If A only appears in a single translation unit, the best way to silence the warning is to give it internal linkage by putting it in an anonymous namespace as well. The compiler doesn't give this warning for types defined in the main .C file, as those are unlikely to have multiple definitions. `-Wsubobject-linkage` is enabled by default.

`-Weffc++` (C++ and Objective-C++ only)
: Warn about violations of the following style guidelines from Scott Meyers' *Effective C++* series of books:

- Define a copy constructor and an assignment operator for classes with dynamically-allocated memory.

- Prefer initialization to assignment in constructors.
- Have `operator=` return a reference to `*this`.
- Don't try to return a reference when you must return an object.
- Distinguish between prefix and postfix forms of increment and decrement operators.
- Never overload `&&`, `||`, or `,`.

This option also enables `-Wnon-virtual-dtor`, which is also one of the effective C++ recommendations. However, the check is extended to warn about the lack of virtual destructor in accessible non-polymorphic bases classes too.

When selecting this option, be aware that the standard library headers do not obey all of these guidelines; use '`grep -v`' to filter out those warnings.

`-Wno-exceptions` (C++ and Objective-C++ only)
Disable the warning about the case when an exception handler is shadowed by another handler, which can point out a wrong ordering of exception handlers.

Warn about a class that is found to be incomplete, or a function with auto return type that has not yet been deduced, in a context where that causes substitution failure rather than an error, and then the class or function is defined later in the translation unit. This is problematic because template instantiations or concept checks could have different results if they first occur either before or after the definition.

This warning is enabled by default. `-Wsfinae-incomplete=2` adds a warning at the point of substitution failure, to make it easier to track down problems flagged by the default mode.

`-Wstrict-null-sentinel` (C++ and Objective-C++ only)
Warn about the use of an uncasted `NULL` as sentinel. When compiling only with GCC this is a valid sentinel, as `NULL` is defined to `__null`. Although it is a null pointer constant rather than a null pointer, it is guaranteed to be of the same size as a pointer. But this use is not portable across different compilers.

`-Wno-non-c-typedef-for-linkage` (C++ and Objective-C++ only)
Disable pedwarn for unnamed classes with a typedef name for linkage purposes containing C++ specific members, base classes, default member initializers or lambda expressions, including those on nested member classes.

```
typedef struct {
  int a; // non-static data members are ok
  struct T { int b; }; // member classes too
  enum E { E1, E2, E3 }; // member enumerations as well
  int c = 42; // default member initializers are not ok
  struct U : A { int c; }; // classes with base classes are not ok
  typedef int V; // typedef is not ok
  using W = int; // using declaration is not ok
  decltype([](){}) x; // lambda expressions not ok
} S;
```

In all these cases, the tag name S should be added after the struct keyword.

`-Wno-non-template-friend` (C++ and Objective-C++ only)
Disable warnings when non-template friend functions are declared within a template. In very old versions of GCC that predate implementation of the ISO

standard, declarations such as 'friend int foo(int)', where the name of the friend is an unqualified-id, could be interpreted as a particular specialization of a template function; the warning exists to diagnose compatibility problems, and is enabled by default.

`-Wold-style-cast` (C++ and Objective-C++ only)
: Warn if an old-style (C-style) cast to a non-void type is used within a C++ program. The new-style casts (`dynamic_cast`, `static_cast`, `reinterpret_cast`, and `const_cast`) are less vulnerable to unintended effects and much easier to search for.

`-Woverloaded-virtual` (C++ and Objective-C++ only)
`-Woverloaded-virtual=`*n*
: Warn when a function declaration hides virtual functions from a base class. For example, in:

```
struct A {
  virtual void f();
};

struct B: public A {
  void f(int); // does not override
};
```

the `A` class version of `f` is hidden in `B`, and code like:

```
B* b;
b->f();
```

fails to compile.

In cases where the different signatures are not an accident, the simplest solution is to add a using-declaration to the derived class to un-hide the base function, e.g. add `using A::f;` to `B`.

The optional level suffix controls the behavior when all the declarations in the derived class override virtual functions in the base class, even if not all of the base functions are overridden:

```
struct C {
  virtual void f();
  virtual void f(int);
};

struct D: public C {
  void f(int); // does override
}
```

This pattern is less likely to be a mistake; if D is only used virtually, the user might have decided that the base class semantics for some of the overloads are fine.

At level 1, this case does not warn; at level 2, it does. `-Woverloaded-virtual` by itself selects level 2. Level 1 is included in `-Wall`.

`-Wno-pmf-conversions` (C++ and Objective-C++ only)
: Disable the diagnostic for converting a bound pointer to member function to a plain pointer.

`-Wsign-promo` (C++ and Objective-C++ only)
Warn when overload resolution chooses a promotion from unsigned or enumerated type to a signed type, over a conversion to an unsigned type of the same size. Previous versions of G++ tried to preserve unsignedness, but the standard mandates the current behavior.

`-Wtemplates` (C++ and Objective-C++ only)
Warn when a primary template declaration is encountered. Some coding rules disallow templates, and this may be used to enforce that rule. The warning is inactive inside a system header file, such as the STL, so one can still use the STL. One may also instantiate or specialize templates.

`-Wmismatched-new-delete` (C++ and Objective-C++ only)
Warn for mismatches between calls to `operator new` or `operator delete` and the corresponding call to the allocation or deallocation function. This includes invocations of C++ `operator delete` with pointers returned from either mismatched forms of `operator new`, or from other functions that allocate objects for which the `operator delete` isn't a suitable deallocator, as well as calls to other deallocation functions with pointers returned from `operator new` for which the deallocation function isn't suitable.

For example, the `delete` expression in the function below is diagnosed because it doesn't match the array form of the `new` expression the pointer argument was returned from. Similarly, the call to `free` is also diagnosed.

```
void f ()
{
  int *a = new int[n];
  delete a;   // warning: mismatch in array forms of expressions

  char *p = new char[n];
  free (p);   // warning: mismatch between new and free
}
```

The related option `-Wmismatched-dealloc` diagnoses mismatches involving allocation and deallocation functions other than `operator new` and `operator delete`.

`-Wmismatched-new-delete` is included in `-Wall`.

`-Wmismatched-tags` (C++ and Objective-C++ only)
Warn for declarations of structs, classes, and class templates and their specializations with a class-key that does not match either the definition or the first declaration if no definition is provided.

For example, the declaration of `struct Object` in the argument list of `draw` triggers the warning. To avoid it, either remove the redundant class-key `struct` or replace it with `class` to match its definition.

```
class Object {
public:
  virtual ~Object () = 0;
};
void draw (struct Object*);
```

It is not wrong to declare a class with the class-key `struct` as the example above shows. The `-Wmismatched-tags` option is intended to help achieve a consistent style of class declarations. In code that is intended to be portable to Windows-based compilers the warning helps prevent unresolved references due to the difference in the mangling of symbols declared with different class-keys. The option can be used either on its own or in conjunction with `-Wredundant-tags`.

`-Wmultiple-inheritance` (C++ and Objective-C++ only)
: Warn when a class is defined with multiple direct base classes. Some coding rules disallow multiple inheritance, and this may be used to enforce that rule. The warning is inactive inside a system header file, such as the STL, so one can still use the STL. One may also define classes that indirectly use multiple inheritance.

`-Wvirtual-inheritance`
: Warn when a class is defined with a virtual direct base class. Some coding rules disallow multiple inheritance, and this may be used to enforce that rule. The warning is inactive inside a system header file, such as the STL, so one can still use the STL. One may also define classes that indirectly use virtual inheritance.

`-Wno-virtual-move-assign`
: Suppress warnings about inheriting from a virtual base with a non-trivial C++11 move assignment operator. This is dangerous because if the virtual base is reachable along more than one path, it is moved multiple times, which can mean both objects end up in the moved-from state. If the move assignment operator is written to avoid moving from a moved-from object, this warning can be disabled.

`-Wnamespaces`
: Warn when a namespace definition is opened. Some coding rules disallow namespaces, and this may be used to enforce that rule. The warning is inactive inside a system header file, such as the STL, so one can still use the STL. One may also use using directives and qualified names.

`-Wno-template-body` (C++ and Objective-C++ only)
: Disable diagnosing errors when parsing a template, and instead issue an error only upon instantiation of the template. This flag can also be used to downgrade such errors into warnings with `Wno-error=` or `-fpermissive`.

`-Wno-template-id-cdtor` (C++ and Objective-C++ only)
: Disable the warning about the use of simple-template-id as the declarator-id of a constructor or destructor, which became invalid in C++20 via DR 2237. For example:

```
template<typename T> struct S {
  S<T>(); // should be S();
  ~S<T>();  // should be ~S();
};
```

`-Wtemplate-id-cdtor` is enabled by default with `-std=c++20`; it is also enabled by `-Wc++20-compat`.

`-Wtemplate-names-tu-local`
: Warn when a template body hides an exposure of a translation-unit-local entity. In most cases, referring to a translation-unit-local entity (such as an internal

linkage declaration) within an entity that is emitted into a module's CMI is an error. However, within the initializer of a variable, or in the body of a non-inline function, this is not an exposure and no error is emitted.

This can cause variable or function templates to accidentally become unusable if they reference such an entity, because other translation units that import the template will never be able to instantiate it. This warning attempts to detect cases where this might occur. The presence of an explicit instantiation silences the warning.

This flag is enabled by `-Wextra`.

`-Wno-expose-global-module-tu-local`

An exposure of a translation-unit-local entity from a module interface is invalid, as this may cause ODR violations and manifest in link errors or other unexpected behaviour. However, many existing libraries declare TU-local entities in their interface, and avoiding exposures of these entities may be difficult in some cases.

As an extension, GCC allows exposures of internal variables and functions that were declared in the global module fragment. This warning indicates when such an invalid exposure has occurred, and can be silenced using diagnostic pragmas either at the site of the exposure, or at the point of declaration of the internal declaration.

When combined with `-Wtemplate-names-tu-local`, GCC will also warn about non-exposure references to TU-local entities in template bodies. Such templates can still be instantiated in other TUs but the above risks regarding exposures of translation-unit-local entities apply.

This warning is enabled by default, and is upgraded to an error by `-pedantic-errors`.

`-Wno-external-tu-local`

Warn when naming a TU-local entity outside of the translation unit it was declared in. Such declarations will be ignored during name lookup. This can occur when performing ADL from a template declared in the same TU as the internal function:

```
export module M;
template <typename T> void foo(T t) {
  bar(t);
}
struct S {} s;
static void bar(S) {}  // internal linkage

// instantiating foo(s) from outside this TU can see ::bar,
// but naming it there is ill-formed.
```

This can be worked around by making `bar` attached to the global module, using `extern "C++"`.

This warning is enabled by default, and is upgraded to an error by `-pedantic-errors`.

`-Wno-terminate` (C++ and Objective-C++ only)
: Disable the warning about a throw-expression that will immediately result in a call to `terminate`.

`-Wno-vexing-parse` (C++ and Objective-C++ only)
: Warn about the most vexing parse syntactic ambiguity. This warns about the cases when a declaration looks like a variable definition, but the C++ language requires it to be interpreted as a function declaration. For instance:

```
void f(double a) {
  int i();        // extern int i (void);
  int n(int(a));  // extern int n (int);
}
```

Another example:

```
struct S { S(int); };
void f(double a) {
  S x(int(a));   // extern struct S x (int);
  S y(int());    // extern struct S y (int (*) (void));
  S z();         // extern struct S z (void);
}
```

The warning will suggest options how to deal with such an ambiguity; e.g., it can suggest removing the parentheses or using braces instead.

This warning is enabled by default.

`-Wno-class-conversion` (C++ and Objective-C++ only)
: Do not warn when a conversion function converts an object to the same type, to a base class of that type, or to void; such a conversion function will never be called.

`-Wvolatile` (C++ and Objective-C++ only)
: Warn about deprecated uses of the `volatile` qualifier. This includes postfix and prefix `++` and `--` expressions of `volatile`-qualified types, using simple assignments where the left operand is a `volatile`-qualified non-class type for their value, compound assignments where the left operand is a `volatile`-qualified non-class type, `volatile`-qualified function return type, `volatile`-qualified parameter type, and structured bindings of a `volatile`-qualified type. This usage was deprecated in C++20.

Enabled by default with `-std=c++20`. Before `-std=c++20`, enabled with explicit `-Wdeprecated`.

`-Waligned-new`
`-Waligned-new=[none|global|all]`
: Warn about a new-expression of a type that requires greater alignment than the `alignof(std::max_align_t)` but uses an allocation function without an explicit alignment parameter. This option is enabled by `-Wall`.

Normally this only warns about global allocation functions, but `-Waligned-new=all` also warns about class member allocation functions.

`-Wno-placement-new`
`-Wplacement-new=`*n*
: Warn about placement new expressions with undefined behavior, such as constructing an object in a buffer that is smaller than the type of the object. For

example, the placement new expression below is diagnosed because it attempts to construct an array of 64 integers in a buffer only 64 bytes large.

```
char buf [64];
new (buf) int[64];
```

This warning is enabled by default.

`-Wplacement-new=1`
: This is the default warning level of `-Wplacement-new`. At this level the warning is not issued for some strictly undefined constructs that GCC allows as extensions for compatibility with legacy code. For example, the following `new` expression is not diagnosed at this level even though it has undefined behavior according to the C++ standard because it writes past the end of the one-element array.

```
struct S { int n, a[1]; };
S *s = (S *)malloc (sizeof *s + 31 * sizeof s->a[0]);
new (s->a)int [32]();
```

`-Wplacement-new=2`
: At this level, in addition to diagnosing all the same constructs as at level 1, a diagnostic is also issued for placement new expressions that construct an object in the last member of structure whose type is an array of a single element and whose size is less than the size of the object being constructed. While the previous example would be diagnosed, the following construct makes use of the flexible member array extension to avoid the warning at level 2.

```
struct S { int n, a[]; };
S *s = (S *)malloc (sizeof *s + 32 * sizeof s->a[0]);
new (s->a)int [32]();
```

`-Wcatch-value`
`-Wcatch-value=`*n* (C++ and Objective-C++ only)
: Warn about catch handlers that do not catch via reference. With `-Wcatch-value=1` (or `-Wcatch-value` for short) warn about polymorphic class types that are caught by value. With `-Wcatch-value=2` warn about all class types that are caught by value. With `-Wcatch-value=3` warn about all types that are not caught by reference. `-Wcatch-value` is enabled by `-Wall`.

`-Wconditionally-supported` (C++ and Objective-C++ only)
: Warn for conditionally-supported (C++11 [intro.defs]) constructs.

`-Wno-defaulted-function-deleted` (C++ and Objective-C++ only)
: Warn when an explicitly defaulted function is deleted by the compiler. That can occur when the function's declared type does not match the type of the function that would have been implicitly declared. This warning is enabled by default.

`-Wno-delete-incomplete` (C++ and Objective-C++ only)
: Do not warn when deleting a pointer to incomplete type, which may cause undefined behavior at runtime. This warning is enabled by default.

`-Wextra-semi` (C++, Objective-C++ only)

Warn about redundant semicolons. There are various contexts in which an extra semicolon can occur. One is a semicolon after in-class function definitions, which is valid in all C++ dialects (and is never a pedwarn):

```
struct S {
  void foo () {};
};
```

Another is an extra semicolon at namespace scope, which has been allowed since C++11 (therefore is a pedwarn in C++98):

```
struct S {
};
;
```

And yet another is an extra semicolon in class definitions, which has been allowed since C++11 (therefore is a pedwarn in C++98):

```
struct S {
  int a;
  ;
};
```

`-Wno-global-module` (C++ and Objective-C++ only)

Disable the diagnostic for when the global module fragment of a module unit does not consist only of preprocessor directives.

`-Wno-inaccessible-base` (C++, Objective-C++ only)

This option controls warnings when a base class is inaccessible in a class derived from it due to ambiguity. The warning is enabled by default. Note that the warning for ambiguous virtual bases is enabled by the `-Wextra` option.

```
struct A { int a; };

struct B : A { };

struct C : B, A { };
```

`-Wno-inherited-variadic-ctor`

Suppress warnings about use of C++11 inheriting constructors when the base class inherited from has a C variadic constructor; the warning is on by default because the ellipsis is not inherited.

`-Wno-invalid-offsetof` (C++ and Objective-C++ only)

Suppress warnings from applying the `offsetof` macro to a non-POD type. According to the 2014 ISO C++ standard, applying `offsetof` to a non-standard-layout type is undefined. In existing C++ implementations, however, `offsetof` typically gives meaningful results. This flag is for users who are aware that they are writing nonportable code and who have deliberately chosen to ignore the warning about it.

The restrictions on `offsetof` may be relaxed in a future version of the C++ standard.

`-Wsized-deallocation` (C++ and Objective-C++ only)

Warn about a definition of an unsized deallocation function

```
void operator delete (void *) noexcept;
```

```
void operator delete[] (void *) noexcept;
```

without a definition of the corresponding sized deallocation function

```
void operator delete (void *, std::size_t) noexcept;
void operator delete[] (void *, std::size_t) noexcept;
```

or vice versa. Enabled by `-Wextra` along with `-fsized-deallocation`.

`-Wsuggest-final-types`
: Warn about types with virtual methods where code quality would be improved if the type were declared with the C++11 `final` specifier, or, if possible, declared in an anonymous namespace. This allows GCC to more aggressively devirtualize the polymorphic calls. This warning is more effective with link-time optimization, where the information about the class hierarchy graph is more complete.

`-Wsuggest-final-methods`
: Warn about virtual methods where code quality would be improved if the method were declared with the C++11 `final` specifier, or, if possible, its type were declared in an anonymous namespace or with the `final` specifier. This warning is more effective with link-time optimization, where the information about the class hierarchy graph is more complete. It is recommended to first consider suggestions of `-Wsuggest-final-types` and then rebuild with new annotations.

`-Wsuggest-override`
: Warn about overriding virtual functions that are not marked with the `override` keyword.

`-Wno-conversion-null` (C++ and Objective-C++ only)
: Do not warn for conversions between `NULL` and non-pointer types. `-Wconversion-null` is enabled by default.

3.6 Options Controlling Objective-C and Objective-C++ Dialects

(NOTE: This manual does not describe the Objective-C and Objective-C++ languages themselves. See Chapter 2 [Language Standards Supported by GCC], page 3, for references.)

This section describes the command-line options that are only meaningful for Objective-C and Objective-C++ programs. You can also use most of the language-independent GNU compiler options. For example, you might compile a file `some_class.m` like this:

```
gcc -g -fgnu-runtime -O -c some_class.m
```

In this example, `-fgnu-runtime` is an option meant only for Objective-C and Objective-C++ programs; you can use the other options with any language supported by GCC.

Note that since Objective-C is an extension of the C language, Objective-C compilations may also use options specific to the C front-end (e.g., `-Wtraditional`). Similarly, Objective-C++ compilations may use C++-specific options (e.g., `-Wabi`).

Here is a list of options that are *only* for compiling Objective-C and Objective-C++ programs:

`-fconstant-string-class=class-name`
: Use *class-name* as the name of the class to instantiate for each literal string specified with the syntax `@"..."`. The default class name is `NXConstantString` if the GNU runtime is being used, and `NSConstantString` if the NeXT runtime is being used (see below). On Darwin / macOS platforms, the `-fconstant-cfstrings` option, if also present, overrides the `-fconstant-string-class` setting and cause `@"..."` literals to be laid out as constant CoreFoundation strings. Note that `-fconstant-cfstrings` is an alias for the target-specific `-mconstant-cfstrings` equivalent.

`-fgnu-runtime`
: Generate object code compatible with the standard GNU Objective-C runtime. This is the default for most types of systems.

`-fnext-runtime`
: Generate output compatible with the NeXT runtime. This is the default for NeXT-based systems, including Darwin / macOS. The macro `__NEXT_RUNTIME__` is predefined if (and only if) this option is used.

`-fno-nil-receivers`
: Assume that all Objective-C message dispatches (`[receiver message:arg]`) in this translation unit ensure that the receiver is not `nil`. This allows for more efficient entry points in the runtime to be used. This option is only available in conjunction with the NeXT runtime and ABI version 0 or 1.

`-fobjc-abi-version=n`
: Use version *n* of the Objective-C ABI for the selected runtime. This option is currently supported only for the NeXT runtime. In that case, Version 0 is the traditional (32-bit) ABI without support for properties and other Objective-C 2.0 additions. Version 1 is the traditional (32-bit) ABI with support for properties and other Objective-C 2.0 additions. Version 2 is the modern (64-bit) ABI. If nothing is specified, the default is Version 0 on 32-bit target machines, and Version 2 on 64-bit target machines.

`-fobjc-call-cxx-cdtors`
: For each Objective-C class, check if any of its instance variables is a C++ object with a non-trivial default constructor. If so, synthesize a special `- (id) .cxx_construct` instance method which runs non-trivial default constructors on any such instance variables, in order, and then return `self`. Similarly, check if any instance variable is a C++ object with a non-trivial destructor, and if so, synthesize a special `- (void) .cxx_destruct` method which runs all such default destructors, in reverse order.

  The `- (id) .cxx_construct` and `- (void) .cxx_destruct` methods thusly generated only operate on instance variables declared in the current Objective-C class, and not those inherited from superclasses. It is the responsibility of the Objective-C runtime to invoke all such methods in an object's inheritance hierarchy. The `- (id) .cxx_construct` methods are invoked by the runtime immediately after a new object instance is allocated; the `- (void) .cxx_destruct` methods are invoked immediately before the runtime deallocates an object instance.

As of this writing, only the NeXT runtime on Mac OS X 10.4 and later has support for invoking the `- (id) .cxx_construct` and `- (void) .cxx_destruct` methods.

`-fobjc-direct-dispatch`
Allow fast jumps to the message dispatcher. On Darwin this is accomplished via the comm page.

`-fobjc-exceptions`
Enable syntactic support for structured exception handling in Objective-C, similar to what is offered by C++. This option is required to use the Objective-C keywords `@try`, `@throw`, `@catch`, `@finally` and `@synchronized`. This option is available with both the GNU runtime and the NeXT runtime (but not available in conjunction with the NeXT runtime on Mac OS X 10.2 and earlier).

`-fobjc-gc`
Enable garbage collection (GC) in Objective-C and Objective-C++ programs. This option is only available with the NeXT runtime; the GNU runtime has a different garbage collection implementation that does not require special compiler flags.

`-fobjc-nilcheck`
For the NeXT runtime with version 2 of the ABI, check for a nil receiver in method invocations before doing the actual method call. This is the default and can be disabled using `-fno-objc-nilcheck`. Class methods and super calls are never checked for nil in this way no matter what this flag is set to. Currently this flag does nothing when the GNU runtime, or an older version of the NeXT runtime ABI, is used.

`-fobjc-std=objc1`
Conform to the language syntax of Objective-C 1.0, the language recognized by GCC 4.0. This only affects the Objective-C additions to the C/C++ language; it does not affect conformance to C/C++ standards, which is controlled by the separate C/C++ dialect option flags. When this option is used with the Objective-C or Objective-C++ compiler, any Objective-C syntax that is not recognized by GCC 4.0 is rejected. This is useful if you need to make sure that your Objective-C code can be compiled with older versions of GCC.

`-freplace-objc-classes`
Emit a special marker instructing `ld(1)` not to statically link in the resulting object file, and allow `dyld(1)` to load it in at run time instead. This is used in conjunction with the Fix-and-Continue debugging mode, where the object file in question may be recompiled and dynamically reloaded in the course of program execution, without the need to restart the program itself. Currently, Fix-and-Continue functionality is only available in conjunction with the NeXT runtime on Mac OS X 10.3 and later.

`-fzero-link`
When compiling for the NeXT runtime, the compiler ordinarily replaces calls to `objc_getClass("...")` (when the name of the class is known at compile time)

with static class references that get initialized at load time, which improves run-time performance. Specifying the `-fzero-link` flag suppresses this behavior and causes calls to `objc_getClass("...")` to be retained. This is useful in Zero-Link debugging mode, since it allows for individual class implementations to be modified during program execution. The GNU runtime currently always retains calls to `objc_get_class("...")` regardless of command-line options.

`-fno-local-ivars`
: By default instance variables in Objective-C can be accessed as if they were local variables from within the methods of the class they're declared in. This can lead to shadowing between instance variables and other variables declared either locally inside a class method or globally with the same name. Specifying the `-fno-local-ivars` flag disables this behavior thus avoiding variable shadowing issues.

`-fivar-visibility=`[`public`|`protected`|`private`|`package`]
: Set the default instance variable visibility to the specified option so that instance variables declared outside the scope of any access modifier directives default to the specified visibility.

`-gen-decls`
: Dump interface declarations for all classes seen in the source file to a file named *`sourcename`*`.decl`.

`-Wassign-intercept` (Objective-C and Objective-C++ only)
: Warn whenever an Objective-C assignment is being intercepted by the garbage collector.

`-Wno-property-assign-default` (Objective-C and Objective-C++ only)
: Do not warn if a property for an Objective-C object has no assign semantics specified.

`-Wno-protocol` (Objective-C and Objective-C++ only)
: If a class is declared to implement a protocol, a warning is issued for every method in the protocol that is not implemented by the class. The default behavior is to issue a warning for every method not explicitly implemented in the class, even if a method implementation is inherited from the superclass. If you use the `-Wno-protocol` option, then methods inherited from the superclass are considered to be implemented, and no warning is issued for them.

`-Wobjc-root-class` (Objective-C and Objective-C++ only)
: Warn if a class interface lacks a superclass. Most classes will inherit from `NSObject` (or `Object`) for example. When declaring classes intended to be root classes, the warning can be suppressed by marking their interfaces with `__attribute__((objc_root_class))`.

`-Wselector` (Objective-C and Objective-C++ only)
: Warn if multiple methods of different types for the same selector are found during compilation. The check is performed on the list of methods in the final stage of compilation. Additionally, a check is performed for each selector appearing in a `@selector(...)` expression, and a corresponding method for

that selector has been found during compilation. Because these checks scan the method table only at the end of compilation, these warnings are not produced if the final stage of compilation is not reached, for example because an error is found during compilation, or because the `-fsyntax-only` option is being used.

`-Wstrict-selector-match` (Objective-C and Objective-C++ only)
: Warn if multiple methods with differing argument and/or return types are found for a given selector when attempting to send a message using this selector to a receiver of type `id` or `Class`. When this flag is off (which is the default behavior), the compiler omits such warnings if any differences found are confined to types that share the same size and alignment.

`-Wundeclared-selector` (Objective-C and Objective-C++ only)
: Warn if a `@selector(...)` expression referring to an undeclared selector is found. A selector is considered undeclared if no method with that name has been declared before the `@selector(...)` expression, either explicitly in an `@interface` or `@protocol` declaration, or implicitly in an `@implementation` section. This option always performs its checks as soon as a `@selector(...)` expression is found, while `-Wselector` only performs its checks in the final stage of compilation. This also enforces the coding style convention that methods and selectors must be declared before being used.

`-print-objc-runtime-info`
: Generate C header describing the largest structure that is passed by value, if any.

3.7 Options Controlling OpenMP and OpenACC

GCC supports OpenMP extensions to the C, C++, and Fortran languages with the `-fopenmp` option. Similarly, OpenACC extensions are supported in all three languages with `-fopenacc`. See Section 6.7 [OpenMP], page 749, and Section 6.8 [OpenACC], page 750, for an overview of these extensions.

`-foffload=disable`
`-foffload=default`
`-foffload=`*`target-list`*
: Specify for which OpenMP and OpenACC offload targets code should be generated. The default behavior, equivalent to `-foffload=default`, is to generate code for all supported offload targets. The `-foffload=disable` form generates code only for the host fallback, while `-foffload=`*`target-list`* generates code only for the specified comma-separated list of offload targets.

  Offload targets are specified in GCC's internal target-triplet format. You can run the compiler with `-v` to show the list of configured offload targets under `OFFLOAD_TARGET_NAMES`.

`-foffload-options=`*`options`*
`-foffload-options=`*`target-triplet-list`*`=`*`options`*
: With `-foffload-options=`*`options`*, GCC passes the specified *options* to the compilers for all enabled offloading targets. You can specify options that apply

only to a specific target or targets by using the `-foffload-options=`*target-list*`=`*options* form. The *target-list* is a comma-separated list in the same format as for the `-foffload=` option.

Typical command lines are

```
-foffload-options='-fno-math-errno -ffinite-math-only' \
        -foffload-options=nvptx-none=-latomic
-foffload-options=amdgcn-amdhsa=-march=gfx906
```

`-fopenacc`

Enable handling of OpenACC directives '`#pragma acc`' in C/C++ and '`!$acc`' in free-form Fortran and '`!$acc`', '`c$acc`' and '`*$acc`' in fixed-form Fortran. This option implies `-pthread`, and thus is only supported on targets that have support for `-pthread`.

`-fopenacc-dim=`*geom*

Specify default compute dimensions for parallel offload regions that do not explicitly specify them. The *geom* value is a triple of '`:`'-separated sizes, in order *gang*, *worker*, and *vector*. A size can be omitted, to use a target-specific default value.

`-fopenmp`

Enable handling of OpenMP directives '`#pragma omp`', '`[[omp::directive(...)]]`', '`[[omp::decl(...)]]`', and '`[[omp::sequence(...)]]`' in C/C++. In Fortran, it enables '`!$omp`' and the conditional compilation sentinel '`!$`'. In fixed source form Fortran, the sentinels can also start with '`c`' or '`*`'.

This option implies `-pthread`, and thus is only supported on targets that have support for `-pthread`. `-fopenmp` implies `-fopenmp-simd`.

`-fopenmp-simd`

Enable handling of OpenMP's `simd`, `declare simd`, `declare reduction`, `assume`, `ordered`, `scan` and `loop` directive, and of combined or composite directives with `simd` as constituent with `#pragma omp`, `[[omp::directive(...)]]`, `[[omp::sequence(...)]]` and `[[omp::decl(...)]]` in C/C++ and `!$omp` in Fortran. It additionally enables the conditional compilation sentinel '`!$`' in Fortran. In fixed source form Fortran, the sentinels can also start with '`c`' or '`*`'. Other OpenMP directives are ignored. Unless `-fopenmp` is additionally specified, the `loop` region binds to the current task region, independent of the specified `bind` clause.

`-fopenmp-target-simd-clone`
`-fopenmp-target-simd-clone=`*device-type*

In addition to generating SIMD clones for functions marked with the `declare simd` directive, GCC also generates clones for functions marked with the OpenMP `declare target` directive that are suitable for vectorization when this option is in effect. The *device-type* may be one of `none`, `host`, `nohost`, and `any`, which correspond to keywords for the `device_type` clause of the `declare target` directive; clones are generated for the intersection of devices specified. `-fopenmp-target-simd-clone` is equivalent to `-fopenmp-target-simd-clone=any` and `-fno-openmp-target-simd-clone` is equivalent to `-fopenmp-target-simd-clone=none`.

At -O2 and higher (but not -Os or -Og) this optimization defaults to -fopenmp-target-simd-clone=nohost; otherwise it is disabled by default.

3.8 Options to Control Diagnostic Messages Formatting

Traditionally, diagnostic messages have been formatted irrespective of the output device's aspect (e.g. its width, . . .). You can use the options described below to control the formatting algorithm for diagnostic messages, e.g. how many characters per line, how often source location information should be reported. Note that some language front ends may not honor these options.

`-fmessage-length=`*n*

Try to format error messages so that they fit on lines of about *n* characters. If *n* is zero, then no line-wrapping is done; each error message appears on a single line. This is the default for all front ends.

Note - this option also affects the display of the '#error' and '#warning' preprocessor directives, and the 'deprecated' function/type/variable attribute. It does not however affect the 'pragma GCC warning' and 'pragma GCC error' pragmas.

`-fdiagnostics-plain-output`

This option requests that diagnostic output look as plain as possible, which may be useful when running dejagnu or other utilities that need to parse diagnostics output and prefer that it remain more stable over time. -fdiagnostics-plain-output is currently equivalent to the following options:

```
-fno-diagnostics-show-caret
-fno-diagnostics-show-line-numbers
-fdiagnostics-color=never
-fdiagnostics-urls=never
-fdiagnostics-path-format=separate-events
-fdiagnostics-text-art-charset=none
-fno-diagnostics-show-event-links
-fno-diagnostics-show-nesting
```

In the future, if GCC changes the default appearance of its diagnostics, the corresponding option to disable the new behavior will be added to this list.

`-fdiagnostics-show-location=once`

Only meaningful in line-wrapping mode. Instructs the diagnostic messages reporter to emit source location information *once*; that is, in case the message is too long to fit on a single physical line and has to be wrapped, the source location won't be emitted (as prefix) again, over and over, in subsequent continuation lines. This is the default behavior.

`-fdiagnostics-show-location=every-line`

Only meaningful in line-wrapping mode. Instructs the diagnostic messages reporter to emit the same source location information (as prefix) for physical lines that result from the process of breaking a message which is too long to fit on a single line.

`-fdiagnostics-color[=WHEN]`
`-fno-diagnostics-color`

Use color in diagnostics. *WHEN* is '`never`', '`always`', or '`auto`'. The default depends on how the compiler has been configured, it can be any of the above *WHEN* options or also '`never`' if `GCC_COLORS` environment variable isn't present in the environment, and '`auto`' otherwise. '`auto`' makes GCC use color only when the standard error is a terminal, and when not executing in an emacs shell. The forms `-fdiagnostics-color` and `-fno-diagnostics-color` are aliases for `-fdiagnostics-color=always` and `-fdiagnostics-color=never`, respectively.

The colors are defined by the environment variable `GCC_COLORS`. Its value is a colon-separated list of capabilities and Select Graphic Rendition (SGR) substrings. SGR commands are interpreted by the terminal or terminal emulator. (See the section in the documentation of your text terminal for permitted values and their meanings as character attributes.) These substring values are integers in decimal representation and can be concatenated with semicolons. Common values to concatenate include '`1`' for bold, '`4`' for underline, '`5`' for blink, '`7`' for inverse, '`39`' for default foreground color, '`30`' to '`37`' for foreground colors, '`90`' to '`97`' for 16-color mode foreground colors, '`38;5;0`' to '`38;5;255`' for 88-color and 256-color modes foreground colors, '`49`' for default background color, '`40`' to '`47`' for background colors, '`100`' to '`107`' for 16-color mode background colors, and '`48;5;0`' to '`48;5;255`' for 88-color and 256-color modes background colors.

The default `GCC_COLORS` is

```
error=01;31:warning=01;35:note=01;36:range1=32:range2=34:locus=01:\
quote=01:path=01;36:fixit-insert=32:fixit-delete=31:\
diff-filename=01:diff-hunk=32:diff-delete=31:diff-insert=32:\
type-diff=01;32:fnname=01;32:targs=35:valid=01;31:invalid=01;32\
highlight-a=01;32:highlight-b=01;34
```

where '`01;31`' is bold red, '`01;35`' is bold magenta, '`01;36`' is bold cyan, '`32`' is green, '`34`' is blue, '`01`' is bold, and '`31`' is red. Setting `GCC_COLORS` to the empty string disables colors. Supported capabilities are as follows.

`error=` SGR substring for error: markers.

`warning=` SGR substring for warning: markers.

`note=` SGR substring for note: markers.

`path=` SGR substring for colorizing paths of control-flow events as printed via `-fdiagnostics-path-format=`, such as the identifiers of individual events and lines indicating interprocedural calls and returns.

`range1=` SGR substring for first additional range.

`range2=` SGR substring for second additional range.

`locus=` SGR substring for location information, '`file:line`' or '`file:line:column`' etc.

`quote=` SGR substring for information printed within quotes.

`fnname=` SGR substring for names of C++ functions.

`targs=` SGR substring for C++ function template parameter bindings.

`fixit-insert=`
: SGR substring for fix-it hints suggesting text to be inserted or replaced.

`fixit-delete=`
: SGR substring for fix-it hints suggesting text to be deleted.

`diff-filename=`
: SGR substring for filename headers within generated patches.

`diff-hunk=`
: SGR substring for the starts of hunks within generated patches.

`diff-delete=`
: SGR substring for deleted lines within generated patches.

`diff-insert=`
: SGR substring for inserted lines within generated patches.

`type-diff=`
: SGR substring for highlighting mismatching types within template arguments in the C++ frontend.

`valid=` SGR substring for highlighting valid elements within text art diagrams.

`invalid=` SGR substring for highlighting invalid elements within text art diagrams.

`highlight-a=`
`highlight-b=`
: SGR substrings for contrasting two different things within diagnostics, such as a pair of mismatching types. See `-fdiagnostics-show-highlight-colors`.

`-fdiagnostics-urls[=`*`WHEN`*`]`
: Use escape sequences to embed URLs in diagnostics. For example, when `-fdiagnostics-show-option` emits text showing the command-line option controlling a diagnostic, embed a URL for documentation of that option.

WHEN is '`never`', '`always`', or '`auto`'. '`auto`' makes GCC use URL escape sequences only when the standard error is a terminal, and when not executing in an emacs shell or any graphical terminal which is known to be incompatible with this feature, see below.

The default depends on how the compiler has been configured. It can be any of the above *WHEN* options.

GCC can also be configured (via the `--with-diagnostics-urls=auto-if-env` configure-time option) so that the default is affected by environment variables. Under such a configuration, GCC defaults to using '`auto`' if either `GCC_URLS` or `TERM_URLS` environment variables are present and non-empty in the environment of the compiler, or '`never`' if neither are.

However, even with `-fdiagnostics-urls=always` the behavior is dependent on those environment variables: If `GCC_URLS` is set to empty or '`no`', do not embed URLs in diagnostics. If set to '`st`', URLs use ST escape sequences. If set to '`bel`', the default, URLs use BEL escape sequences. Any other non-empty value enables the feature. If `GCC_URLS` is not set, use `TERM_URLS` as a fallback. Note: ST is an ANSI escape sequence, string terminator '`ESC \`', BEL is an ASCII character, CTRL-G that usually sounds like a beep.

At this time GCC tries to detect also a few terminals that are known to not implement the URL feature, and have bugs or at least had bugs in some versions that are still in use, where the URL escapes are likely to misbehave, i.e. print garbage on the screen. That list is currently xfce4-terminal, certain known to be buggy gnome-terminal versions, the linux console, and mingw. This check can be skipped with the `-fdiagnostics-urls=always`.

`-fno-diagnostics-show-option`

By default, each diagnostic emitted includes text indicating the command-line option that directly controls the diagnostic (if such an option is known to the diagnostic machinery). Specifying the `-fno-diagnostics-show-option` flag suppresses that behavior.

`-fno-diagnostics-show-caret`

By default, each diagnostic emitted includes the original source line and a caret '^' indicating the column. This option suppresses this information. The source line is truncated to *n* characters, if the `-fmessage-length=n` option is given. When the output is done to the terminal, the width is limited to the width given by the `COLUMNS` environment variable or, if not set, to the terminal width.

`-fno-diagnostics-show-labels`

By default, when printing source code (via `-fdiagnostics-show-caret`), diagnostics can label ranges of source code with pertinent information, such as the types of expressions:

```
printf ("foo %s bar", long_i + long_j);
             ~^       ~~~~~~~~~~~~~~~
              |              |
              char *         long int
```

This option suppresses the printing of these labels (in the example above, the vertical bars and the "char *" and "long int" text).

`-fno-diagnostics-show-event-links`

By default, when printing execution paths (via `-fdiagnostics-path-format=inline-events`), GCC will print lines connecting related events, such as the line connecting events 1 and 2 in:

```
3 |   if (p)
  |       ^
  |       |
  |       (1) following `false' branch (when `p' is NULL)... ->-+
  |                                                             |
  |                                                             |
```

```
  |+------------------------------------------------------------+
4 ||    return 0;
5 ||  return *p;
  ||         ~
  ||         |
  |+-------->(2) ...to here
  |          (3) dereference of NULL `p'
```

This option suppresses the printing of such connector lines.

`-fno-diagnostics-show-cwe`

Diagnostic messages can optionally have an associated CWE (`https://cwe.mitre.org/index.html`) identifier. GCC itself only provides such metadata for some of the `-fanalyzer` diagnostics. GCC plugins may also provide diagnostics with such metadata. By default, if this information is present, it will be printed with the diagnostic. This option suppresses the printing of this metadata.

`-fno-diagnostics-show-rules`

Diagnostic messages can optionally have rules associated with them, such as from a coding standard, or a specification. GCC itself does not do this for any of its diagnostics, but plugins may do so. By default, if this information is present, it will be printed with the diagnostic. This option suppresses the printing of this metadata.

`-fno-diagnostics-show-highlight-colors`

GCC can use color for emphasis and contrast when printing diagnostic messages and quoting the user's source.

For example, in

```
demo.c: In function `test_bad_format_string_args':
../../src/demo.c:25:18: warning: format `%i' expects argument of type `int', but argument 2 has type `const char *' [-Wformat=]
   25 |   printf("hello %i", msg);
      |                 ~^   ~~~
      |                  |   |
      |                  int const char *
      |                 %s
```

- the `%i` and `int` in the message and the `int` in the quoted source are colored using `highlight-a` (bold green by default), and
- the `const char *` in the message and in the quoted source are both colored using `highlight-b` (bold blue by default).

The intent is to draw the reader's eyes to the relationships between the various aspects of the diagnostic message and the source, using color to group related elements and distinguish between mismatching ones.

This additional colorization is enabled by default if color printing is enabled (as per `-fdiagnostics-color=`), but it can be separately disabled via `-fno-diagnostics-show-highlight-colors`.

`-fno-diagnostics-show-line-numbers`

By default, when printing source code (via `-fdiagnostics-show-caret`), a left margin is printed, showing line numbers. This option suppresses this left margin.

`-fdiagnostics-minimum-margin-width=`*width*

This option controls the minimum width of the left margin printed by `-fdiagnostics-show-line-numbers`. It defaults to 6.

`-fdiagnostics-show-context[=`*depth*`]`
`-fno-diagnostics-show-context`

With this option, the compiler might print the interesting control flow chain that guards the basic block of the statement which has the warning. *depth* is the maximum depth of the control flow chain. Currently, The list of the impacted warning options includes: `-Warray-bounds`, `-Wstringop-overflow`, `-Wstringop-overread`, `-Wstringop-truncation`. and `-Wrestrict`. More warning options might be added to this list in future releases. The forms `-fdiagnostics-show-context` and `-fno-diagnostics-show-context` are aliases for `-fdiagnostics-show-context=1` and `-fdiagnostics-show-context=0`, respectively.

`-fdiagnostics-parseable-fixits`

Emit fix-it hints in a machine-parseable format, suitable for consumption by IDEs. For each fix-it, a line will be printed after the relevant diagnostic, starting with the string "fix-it:". For example:

```
fix-it:"test.c":{45:3-45:21}:"gtk_widget_show_all"
```

The location is expressed as a half-open range, expressed as a count of bytes, starting at byte 1 for the initial column. In the above example, bytes 3 through 20 of line 45 of "test.c" are to be replaced with the given string:

```
00000000011111111112222222222
12345678901234567890123456789
  gtk_widget_showall (dlg);
  ^^^^^^^^^^^^^^^^^^
  gtk_widget_show_all
```

The filename and replacement string escape backslash as "\\", tab as "\t", newline as "\n", double quotes as "\"", non-printable characters as octal (e.g. vertical tab as "\013").

An empty replacement string indicates that the given range is to be removed. An empty range (e.g. "45:3-45:3") indicates that the string is to be inserted at the given position.

`-fdiagnostics-generate-patch`

Print fix-it hints to stderr in unified diff format, after any diagnostics are printed. For example:

```
--- test.c
+++ test.c
@ -42,5 +42,5 @

 void show_cb(GtkDialog *dlg)
 {
-  gtk_widget_showall(dlg);
+  gtk_widget_show_all(dlg);
 }
```

The diff may or may not be colorized, following the same rules as for diagnostics (see `-fdiagnostics-color`).

`-fdiagnostics-show-template-tree`

In the C++ frontend, when printing diagnostics showing mismatching template types, such as:

```
could not convert 'std::map<int, std::vector<double> >()'
  from 'map<[...],vector<double>>' to 'map<[...],vector<float>>
```

the `-fdiagnostics-show-template-tree` flag enables printing a tree-like structure showing the common and differing parts of the types, such as:

```
map<
  [...],
  vector<
    [double != float]>>
```

The parts that differ are highlighted with color ("double" and "float" in this case).

`-fno-elide-type`

By default when the C++ frontend prints diagnostics showing mismatching template types, common parts of the types are printed as "[...]" to simplify the error message. For example:

```
could not convert 'std::map<int, std::vector<double> >()'
  from 'map<[...],vector<double>>' to 'map<[...],vector<float>>
```

Specifying the `-fno-elide-type` flag suppresses that behavior. This flag also affects the output of the `-fdiagnostics-show-template-tree` flag.

`-fdiagnostics-path-format=`*KIND*

Specify how to print paths of control-flow events for diagnostics that have such a path associated with them.

KIND is '`none`', '`separate-events`', or '`inline-events`', the default.

'`none`' means to not print diagnostic paths.

'`separate-events`' means to print a separate "note" diagnostic for each event within the diagnostic. For example:

```
test.c:29:5: error: passing NULL as argument 1 to 'PyList_Append' which requires a non-NULL parameter
test.c:25:10: note: (1) when 'PyList_New' fails, returning NULL
test.c:27:3: note: (2) when 'i < count'
test.c:29:5: note: (3) when calling 'PyList_Append', passing NULL from (1) as argument 1
```

'`inline-events`' means to print the events "inline" within the source code. This view attempts to consolidate the events into runs of sufficiently-close events, printing them as labelled ranges within the source.

For example, the same events as above might be printed as:

```
'test': events 1-3
 25 |   list = PyList_New(0);
    |          ^~~~~~~~~~~~~
    |          |
    |          (1) when 'PyList_New' fails, returning NULL
 26 |
 27 |   for (i = 0; i < count; i++) {
    |   ~~~
    |   |
    |   (2) when 'i < count'
 28 |     item = PyLong_FromLong(random());
 29 |     PyList_Append(list, item);
```

```
        |     ~~~~~~~~~~~~~~~~~~~~~~~~~
        |     |
        |     (3) when calling 'PyList_Append', passing NULL from (1) as argument 1
```

Interprocedural control flow is shown by grouping the events by stack frame, and using indentation to show how stack frames are nested, pushed, and popped.

For example:

```
  'test': events 1-2
    |
    |  133 | {
    |      | ^
    |      | |
    |      | (1) entering 'test'
    |  134 |   boxed_int *obj = make_boxed_int (i);
    |      |                    ~~~~~~~~~~~~~~~~~~
    |      |                    |
    |      |                    (2) calling 'make_boxed_int'
    |
    +--> 'make_boxed_int': events 3-4
           |
           |  120 | {
           |      | ^
           |      | |
           |      | (3) entering 'make_boxed_int'
           |  121 |   boxed_int *result = (boxed_int *)wrapped_malloc (sizeof (boxed_int));
           |      |                                    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
           |      |                                    |
           |      |                                    (4) calling 'wrapped_malloc'
           |
           +--> 'wrapped_malloc': events 5-6
                  |
                  |    7 | {
                  |      | ^
                  |      | |
                  |      | (5) entering 'wrapped_malloc'
                  |    8 |   return malloc (size);
                  |      |          ~~~~~~~~~~~~~
                  |      |          |
                  |      |          (6) calling 'malloc'
                  |
    <-------------+
    |
 'test': event 7
    |
    |  138 |   free_boxed_int (obj);
    |      |   ^~~~~~~~~~~~~~~~~~~~
    |      |   |
    |      |   (7) calling 'free_boxed_int'
    |
(etc)
```

`-fdiagnostics-show-path-depths`

This option provides additional information when printing control-flow paths associated with a diagnostic.

If this is option is provided then the stack depth will be printed for each run of events within `-fdiagnostics-path-format=inline-events`. If provided with `-fdiagnostics-path-format=separate-events`, then the stack depth and function declaration will be appended when printing each event.

This is intended for use by GCC developers and plugin developers when debugging diagnostics that report interprocedural control flow.

`-fno-show-column`
: Do not print column numbers in diagnostics. This may be necessary if diagnostics are being scanned by a program that does not understand the column numbers, such as `dejagnu`.

`-fdiagnostics-column-unit=`*UNIT*
: Select the units for the column number. This affects traditional diagnostics (in the absence of `-fno-show-column`).

The default *UNIT*, '`display`', considers the number of display columns occupied by each character. This may be larger than the number of bytes required to encode the character, in the case of tab characters, or it may be smaller, in the case of multibyte characters. For example, the character "GREEK SMALL LETTER PI (U+03C0)" occupies one display column, and its UTF-8 encoding requires two bytes; the character "SLIGHTLY SMILING FACE (U+1F642)" occupies two display columns, and its UTF-8 encoding requires four bytes.

Setting *UNIT* to '`byte`' changes the column number to the raw byte count in all cases, as was traditionally output by GCC prior to version 11.1.0.

`-fdiagnostics-column-origin=`*ORIGIN*
: Select the origin for column numbers, i.e. the column number assigned to the first column. The default value of 1 corresponds to traditional GCC behavior and to the GNU style guide. Some utilities may perform better with an origin of 0; any non-negative value may be specified.

`-fdiagnostics-escape-format=`*FORMAT*
: When GCC prints pertinent source lines for a diagnostic it normally attempts to print the source bytes directly. However, some diagnostics relate to encoding issues in the source file, such as malformed UTF-8, or issues with Unicode normalization. These diagnostics are flagged so that GCC will escape bytes that are not printable ASCII when printing their pertinent source lines.

This option controls how such bytes should be escaped.

The default *FORMAT*, '`unicode`' displays Unicode characters that are not printable ASCII in the form '`<U+XXXX>`', and bytes that do not correspond to a Unicode character validly-encoded in UTF-8-encoded will be displayed as hexadecimal in the form '`<XX>`'.

For example, a source line containing the string '`before`' followed by the Unicode character U+03C0 ("GREEK SMALL LETTER PI", with UTF-8 encoding 0xCF 0x80) followed by the byte 0xBF (a stray UTF-8 trailing byte), followed by the string '`after`' will be printed for such a diagnostic as:

```
before<U+03C0><BF>after
```

Setting *FORMAT* to '`bytes`' will display all non-printable-ASCII bytes in the form '`<XX>`', thus showing the underlying encoding of non-ASCII Unicode characters. For the example above, the following will be printed:

```
before<CF><80><BF>after
```

`-fdiagnostics-text-art-charset=CHARSET`

Some diagnostics can contain "text art" diagrams: visualizations created from text, intended to be viewed in a monospaced font.

This option selects which characters should be used for printing such diagrams, if any. *CHARSET* is 'none', 'ascii', 'unicode', or 'emoji'.

The 'none' value suppresses the printing of such diagrams. The 'ascii' value will ensure that such diagrams are pure ASCII ("ASCII art"). The 'unicode' value will allow for conservative use of unicode drawing characters (such as box-drawing characters). The 'emoji' value further adds the possibility of emoji in the output (such as emitting U+26A0 WARNING SIGN followed by U+FE0F VARIATION SELECTOR-16 to select the emoji variant of the character).

The default is 'emoji', except when the environment variable `LANG` is set to 'C', in which case the default is 'ascii'.

`-fno-diagnostics-show-nesting`

Some GCC diagnostics have an internal tree-like structure of nested sub-diagnostics, such as for problems when instantiating C++ templates.

By default GCC uses indentation and bullet points in its text output to show the nesting structure of these diagnostics, moves location information to separate lines to make the structure clearer, and eliminates redundant repeated information.

Selecting `-fno-diagnostics-show-nesting` suppresses this indentation, reformatting, and elision, restoring an older 'look" for the diagnostics.

`-fno-diagnostics-show-nesting-locations`

When `fdiagnostics-show-nesting` is enabled, file names and line- and column- numbers are displayed on separate lines from the messages. This location information can be disabled altogether with `-fno-diagnostics-show-nesting-locations`. This option exists for use by GCC developers, for writing DejaGnu test cases.

`-fdiagnostics-show-nesting-levels`

When `fdiagnostics-show-nesting` is enabled, use `fdiagnostics-show-nesting-levels` to also display numbers showing the depth of the nesting. This option exists for use by GCC developers for debugging nested diagnostics, but may be of use to plugin authors.

`-fdiagnostics-format=FORMAT`

Select a different format for printing diagnostics. *FORMAT* is 'text', 'sarif-stderr' or 'sarif-file'.

Using this option replaces any additional "output sinks" added by `-fdiagnostics-add-output=`, or that set by `-fdiagnostics-set-output=`.

The default is 'text'.

The 'sarif-stderr' and 'sarif-file' formats both emit diagnostics in SARIF Version 2.1.0 format, either to stderr, or to a file named *source*`.sarif`, respectively.

`-fdiagnostics-add-output=DIAGNOSTICS-OUTPUT-SPEC`

Add an additional "output sink" for emitting diagnostics.

DIAGNOSTICS-OUTPUT-SPEC should specify a scheme, optionally followed by `:` and one or more *KEY*=*VALUE* pairs, in this form:

```
SCHEME
SCHEME:KEY=VALUE
SCHEME:KEY=VALUE,KEY2=VALUE2
```

etc.

Schemes, keys, or values with a name prefixed "experimental" may change or be removed without notice.

SCHEME can be

`text` Emit diagnostics to stderr using GCC's classic text output format.

Supported keys are:

`color=[yes|no]`
Override colorization settings from `-fdiagnostics-color` for this text output.

`show-nesting=[yes|no]`
Enable a mode that emphasizes hierarchical relationships within diagnostics messages, as per `-fdiagnostics-show-nesting`. Defaults to `yes`.

`show-nesting-locations=[yes|no]`
If `show-nesting=yes`, then by default locations are shown; set this key to `no` to disable printing such locations. This exists for use by GCC developers, for writing DejaGnu test cases.

`show-nesting-levels=[yes|no]`
This is a debugging option for use with `show-nesting=yes`. Set this key to `yes` to print explicit nesting levels in the output. This exists for use by GCC developers.

`sarif` Emit diagnostics to a file in SARIF format.

Supported keys are:

`file=FILENAME`
Specify the filename to write the SARIF output to, potentially with a leading absolute or relative path. If not specified, it defaults to `source.sarif`.

`serialization=[json]`
Specify the serialization format to use when writing out the SARIF. Currently this can only be `json`, but is present as an extension point for experimenting with other serializations.

`version=[2.1|2.2-prerelease]`
: Specify the version of SARIF to use for the output. If not specified, defaults to 2.1. `2.2-prerelease` uses an unofficial draft of the future SARIF 2.2 specification and should only be used for experimentation in this release.

There is also this key intended for use by GCC developers, rather than end-users, and subject to change or removal without notice:

`state-graphs=[yes|no]`
: This is a debugging feature and defaults to `no`. If `state-graphs=yes`, then attempt to capture detailed state information from `-fanalyzer` in the generated SARIF.

`experimental-html`
: Emit diagnostics to a file in HTML format. This scheme is experimental, and may go away in future GCC releases. The keys and details of the output are also subject to change.

Supported keys are:

`css=[yes|no]`
: Add an embedded <style> to the generated HTML. Defaults to yes.

`file=`*`FILENAME`*
: Specify the filename to write the HTML output to, potentially with a leading absolute or relative path. If not specified, it defaults to *`source`*`.html`.

`javascript=[yes|no]`
: Add an embedded <script> to the generated HTML providing a barebones UI for viewing results. Defaults to yes.

There are also these keys intended for use by GCC developers, rather than end-users, and subject to change or removal without notice:

`show-state-diagrams=[yes|no]`
: This is a debugging feature and defaults to `no`. If `show-state-diagrams=yes`, then attempt to use `dot` to generate SVG diagrams in the generated HTML, visualizing the state at each event in a diagnostic path. These are visible by pressing “j” and “k” to single-step forward and backward through events. Enabling this option will slow down HTML generation.

`show-graph-dot-src=[yes|no]`
: This is a debugging feature and defaults to `no`. If `show-graph-dot-src=yes` then if `show-state-diagrams=yes`, the generated state diagrams will also

show the .dot source input to GraphViz used for the diagram.

`show-graph-sarif=[yes|no]`
: This is a debugging feature and defaults to `no`. If `show-graph-sarif=yes` then if `show-state-diagrams=yes`, the generated state diagrams will also show a SARIF representation of the state.

For example,

```
-fdiagnostics-add-output=sarif:version=2.1,file=foo.2.1.sarif
-fdiagnostics-add-output=sarif:version=2.2-prerelease,file=foo.2.2.sarif
```

would add a pair of outputs, each writing to a different file, using versions 2.1 and 2.2 of the SARIF standard respectively.

In EBNF:

```
diagnostics-output-specifier = diagnostics-output-name
                                    | diagnostics-output-name, ":", key-value-pairs;

diagnostics-output-name = "text" | "sarif" | "experimental-html";

key-value-pairs = key-value-pair
                     | key-value-pair "," key-value-pairs;

key-value-pair = key "=" value;

key = ? string without a '=' ? ;
value = ? string without a ',' ? ;
```

`-fdiagnostics-set-output=`*`DIAGNOSTICS-OUTPUT-SPEC`*
: This works in a similar way to `-fdiagnostics-add-output=` except that instead of adding an additional "output sink" for diagnostics, it replaces all existing output sinks, such as from `-fdiagnostics-format=`, `-fdiagnostics-add-output=`, or a prior call to `-fdiagnostics-set-output=`.

`-fno-diagnostics-json-formatting`
: By default, when JSON is emitted for diagnostics (via `-fdiagnostics-format=sarif-stderr` or `-fdiagnostics-format=sarif-file`), GCC will add newlines and indentation to visually emphasize the hierarchical structure of the JSON.

Use `-fno-diagnostics-json-formatting` to suppress this whitespace. It must be passed before the option it is to affect.

This is intended for compatibility with tools that do not expect the output to contain newlines, such as that emitted by older GCC releases.

3.9 Options to Request or Suppress Warnings

Warnings are diagnostic messages that report constructions that are not inherently erroneous but that are risky or suggest there may have been an error.

The following language-independent options do not enable specific warnings but control the kinds of diagnostics produced by GCC.

`-fsyntax-only`
: Check the code for syntax errors, but don't do anything beyond that.

`-fmax-errors=`*n*
: Limits the maximum number of error messages to *n*, at which point GCC bails out rather than attempting to continue processing the source code. If *n* is 0 (the default), there is no limit on the number of error messages produced. If `-Wfatal-errors` is also specified, then `-Wfatal-errors` takes precedence over this option.

`-w`
`--no-warnings`
: Inhibit all warning messages.

`-Werror`
: Turn all warnings into errors.

`-Werror=`
: Turn the specified warning into an error. The specifier for a warning is appended; for example `-Werror=switch` turns the warnings controlled by `-Wswitch` into errors. This switch takes a negative form, to be used to negate `-Werror` for specific warnings; for example `-Wno-error=switch` makes `-Wswitch` warnings not be errors, even when `-Werror` is in effect.

  The warning message for each controllable warning includes the option that controls the warning. That option can then be used with `-Werror=` and `-Wno-error=` as described above. (Printing of the option in the warning message can be disabled using the `-fno-diagnostics-show-option` flag.)

  Note that specifying `-Werror=`*foo* automatically implies `-W`*foo*. However, `-Wno-error=`*foo* does not imply anything.

`-Wfatal-errors`
: This option causes the compiler to abort compilation on the first error occurred rather than trying to keep going and printing further error messages.

You can request many specific warnings with options beginning with '`-W`', for example `-Wunused-variable` to request warnings on declarations of variables that are never used. Each of these specific warning options also has a negative form beginning with '`-Wno-`' to turn off warnings; for example, `-Wno-unused-variable`. This manual lists only one of the two forms, whichever is not the default. For further language-specific options also refer to Section 3.5 [C++ Dialect Options], page 52, and Section 3.6 [Objective-C and Objective-C++ Dialect Options], page 82. Additional warnings can be produced by enabling the static analyzer; See Section 3.10 [Static Analyzer Options], page 169.

Some options, such as `-Wall` and `-Wextra`, turn on other options, such as `-Wunused`, which may turn on further options, such as `-Wunused-variable`. The combined effect of positive and negative forms is that more specific options have priority over less specific ones, independently of their position in the command line. For options of the same specificity, the last one takes effect. Options enabled or disabled via pragmas (see Section 6.5.13 [Diagnostic Pragmas], page 742) take effect as if they appeared at the end of the command line.

When an unrecognized warning option is requested (e.g., `-Wunknown-warning`), GCC gives an error stating that the option is not recognized. However, if the `-Wno-` form is used, the behavior is slightly different: no diagnostic is produced for `-Wno-unknown-warning` unless other diagnostics are being produced. This allows the use of new `-Wno-` options with old compilers, but if something goes wrong, the compiler warns that an unrecognized option is present.

The effectiveness of some warnings depends on optimizations also being enabled. For example, `-Wsuggest-final-types` is more effective with link-time optimization. Some other warnings may not be issued at all unless optimization is enabled. While optimization in general improves the efficacy of warnings about control and data-flow problems, in some cases it may also cause false positives.

`-Wpedantic`
`-pedantic`
`--pedantic`

Issue all the warnings demanded by strict ISO C and ISO C++; diagnose all programs that use forbidden extensions, and some other programs that do not follow ISO C and ISO C++. This follows the version of the ISO C or C++ standard specified by any `-std` option used.

Valid ISO C and ISO C++ programs should compile properly with or without this option (though a rare few require `-ansi` or a `-std` option specifying the version of the standard). However, without this option, certain GNU extensions and traditional C and C++ features are supported as well. With this option, they are diagnosed (or rejected with `-pedantic-errors`).

`-Wpedantic` does not cause warning messages for use of the alternate keywords whose names begin and end with '`__`'. This alternate format can also be used to disable warnings for non-ISO '`__intN`' types, i.e. '`__intN__`'. Pedantic warnings are also disabled in the expression that follows `__extension__`. However, only system header files should use these escape routes; application programs should avoid them. See Section 6.12.23 [Alternate Keywords], page 824.

Some warnings about non-conforming programs are controlled by options other than `-Wpedantic`; in many cases they are implied by `-Wpedantic` but can be disabled separately by their specific option, e.g. `-Wpedantic -Wno-pointer-sign`.

Where the standard specified with `-std` represents a GNU extended dialect of C, such as '`gnu90`' or '`gnu99`', there is a corresponding *base standard*, the version of ISO C on which the GNU extended dialect is based. Warnings from `-Wpedantic` are given where they are required by the base standard. (It does not make sense for such warnings to be given only for features not in the specified GNU C dialect, since by definition the GNU dialects of C include all features the compiler supports with the given option, and there would be nothing to warn about.)

`-pedantic-errors`
`--pedantic-errors`

Give an error whenever the *base standard* (see `-Wpedantic`) requires a diagnostic, in some cases where there is undefined behavior at compile-time and in some other cases that do not prevent compilation of programs that are valid according to the standard. This is not equivalent to `-Werror=pedantic`: the latter option is unlikely to be useful, as it only makes errors of the diagnostics that are controlled by `-Wpedantic`, whereas this option also affects required diagnostics that are always enabled or controlled by options other than `-Wpedantic`.

If you want the required diagnostics that are warnings by default to be errors instead, but don't also want to enable the `-Wpedantic` diagnostics, you can specify `-pedantic-errors -Wno-pedantic` (or `-pedantic-errors -Wno-error=pedantic` to enable them but only as warnings).

Some required diagnostics are errors by default, but can be reduced to warnings using `-fpermissive` or their specific warning option, e.g. `-Wno-error=narrowing`.

Some diagnostics for non-ISO practices are controlled by specific warning options other than `-Wpedantic`, but are also made errors by `-pedantic-errors`. For instance:

`-Wattributes` (for standard attributes)
`-Wchanges-meaning` (C++)
`-Wcomma-subscript` (C++23 or later)
`-Wdeclaration-after-statement` (C90 or earlier)
`-Welaborated-enum-base` (C++11 or later)
`-Wimplicit-int` (C99 or later)
`-Wimplicit-function-declaration` (C99 or later)
`-Wincompatible-pointer-types`
`-Wint-conversion`
`-Wlong-long` (C90 or earlier)
`-Wmain`
`-Wnarrowing` (C++11 or later)
`-Wpointer-arith`
`-Wpointer-sign`
`-Wincompatible-pointer-types`
`-Wregister` (C++17 or later)
`-Wvla` (C90 or earlier)
`-Wwrite-strings` (C++11 or later)

`-fpermissive`

Downgrade some required diagnostics about nonconformant code from errors to warnings. Thus, using `-fpermissive` allows some nonconforming code to compile. Some C++ diagnostics are controlled only by this flag, but it also downgrades some C and C++ diagnostics that have their own flag:

`-Wabbreviated-auto-in-template-arg` (C++ and Objective-C++ only)
`-Wdeclaration-missing-parameter-type` (C and Objective-C only)
`-Wimplicit-function-declaration` (C and Objective-C only)
`-Wimplicit-int` (C and Objective-C only)
`-Wincompatible-pointer-types` (C and Objective-C only)
`-Wint-conversion` (C and Objective-C only)
`-Wnarrowing` (C++ and Objective-C++ only)
`-Wreturn-mismatch` (C and Objective-C only)
`-Wtemplate-body` (C++ and Objective-C++ only)

The `-fpermissive` option is the default for historic C language modes (`-std=c89`, `-std=gnu89`, `-std=c90`, `-std=gnu90`).

`-Wall`
`--all-warnings`

This enables all the warnings about constructions that some users consider questionable, and that are easy to avoid (or modify to prevent the warning), even in conjunction with macros. This also enables some language-specific warnings described in Section 3.5 [C++ Dialect Options], page 52, and Section 3.6 [Objective-C and Objective-C++ Dialect Options], page 82.

`-Wall` turns on the following warning flags:

`-Waddress`
`-Waligned-new` (C++ and Objective-C++ only)
`-Warray-bounds=1` (only with `-O2`)
`-Warray-compare`
`-Warray-parameter=2`
`-Wbool-compare`
`-Wbool-operation`
`-Wc++11-compat -Wc++14-compat -Wc++17compat -Wc++20compat`
`-Wcatch-value` (C++ and Objective-C++ only)
`-Wchar-subscripts`
`-Wclass-memaccess` (C++ and Objective-C++ only)
`-Wcomment`
`-Wdangling-else`
`-Wdangling-pointer=2`
`-Wdelete-non-virtual-dtor` (C++ and Objective-C++ only)
`-Wduplicate-decl-specifier` (C and Objective-C only)
`-Wenum-compare` (in C/ObjC; this is on by default in C++)
`-Wenum-int-mismatch` (C and Objective-C only)
`-Wformat=1`
`-Wformat-contains-nul`
`-Wformat-diag`
`-Wformat-extra-args`
`-Wformat-overflow=1`
`-Wformat-truncation=1`
`-Wformat-zero-length`
`-Wframe-address`
`-Wimplicit` (C and Objective-C only)
`-Wimplicit-function-declaration` (C and Objective-C only)
`-Wimplicit-int` (C and Objective-C only)
`-Winfinite-recursion`
`-Winit-self` (C++ and Objective-C++ only)
`-Wint-in-bool-context`
`-Wlogical-not-parentheses`
`-Wmain` (only for C/ObjC and unless `-ffreestanding`)
`-Wmaybe-uninitialized`
`-Wmemset-elt-size`
`-Wmemset-transposed-args`
`-Wmisleading-indentation` (only for C/C++)
`-Wmismatched-dealloc`
`-Wmismatched-new-delete` (C++ and Objective-C++ only)
`-Wmissing-attributes`
`-Wmissing-braces` (only for C/ObjC)
`-Wmultistatement-macros`
`-Wnarrowing` (C++ and Objective-C++ only)
`-Wnonnull`
`-Wnonnull-compare`
`-Wopenmp-simd` (C and C++ only)
`-Woverloaded-virtual=1` (C++ and Objective-C++ only)

```
-Wpacked-not-aligned
-Wparentheses
-Wpessimizing-move (C++ and Objective-C++ only)
-Wpointer-sign (only for C/ObjC)
-Wrange-loop-construct (C++ and Objective-C++ only)
-Wreorder (C++ and Objective-C++ only)
-Wrestrict
-Wreturn-type
-Wself-move (C++ and Objective-C++ only)
-Wsequence-point
-Wsign-compare (C++ and Objective-C++ only)
-Wsizeof-array-div
-Wsizeof-pointer-div
-Wsizeof-pointer-memaccess
-Wstrict-aliasing
-Wstrict-overflow=1
-Wswitch
-Wtautological-compare
-Wtrigraphs
-Wuninitialized
-Wunknown-pragmas
-Wunused
-Wunused-but-set-variable
-Wunused-const-variable=1 (only for C/ObjC)
-Wunused-function
-Wunused-label
-Wunused-local-typedefs
-Wunused-value
-Wunused-variable
-Wuse-after-free=2
-Wvla-parameter
-Wvolatile-register-var
-Wzero-length-bounds
```

Note that some warning flags are not implied by `-Wall`. Some of them warn about constructions that users generally do not consider questionable, but which occasionally you might wish to check for; others warn about constructions that are necessary or hard to avoid in some cases, and there is no simple way to modify the code to suppress the warning. Some of them are enabled by `-Wextra` but many of them must be enabled individually.

`-Wextra`
`--extra-warnings`

This enables some extra warning flags that are not enabled by `-Wall`. (This option used to be called `-W`. The older name is still supported, but the newer name is more descriptive.)

```
-Wabsolute-value (only for C/ObjC)
-Walloc-size
-Wcalloc-transposed-args
-Wcast-function-type
-Wclobbered
-Wdangling-reference (C++ only)
-Wdeprecated-copy (C++ and Objective-C++ only)
-Wempty-body
-Wenum-conversion (only for C/ObjC)
-Wexpansion-to-defined
-Wignored-qualifiers  (only for C/C++)
```

-Wimplicit-fallthrough=3
-Wmaybe-uninitialized
-Wmissing-field-initializers
-Wmissing-parameter-name (C/ObjC only)
-Wmissing-parameter-type (C/ObjC only)
-Wold-style-declaration (C/ObjC only)
-Wmultiple-parameter-fwd-decl-lists (C/ObjC only)
-Woverride-init (C/ObjC only)
-Wredundant-move (C++ and Objective-C++ only)
-Wshift-negative-value (in C++11 to C++17 and in C99 and newer)
-Wsign-compare (C++ and Objective-C++ only)
-Wsized-deallocation (C++ and Objective-C++ only)
-Wstring-compare
-Wtype-limits
-Wuninitialized
-Wunterminated-string-initialization (C/ObjC only)
-Wunused-parameter (only with -Wunused or -Wall)
-Wunused-but-set-parameter (only with -Wunused or -Wall)

The option `-Wextra` also prints warning messages for the following cases:

- A pointer is compared against integer zero with `<`, `<=`, `>`, or `>=`.
- (C++ only) An enumerator and a non-enumerator both appear in a conditional expression.
- (C++ only) Ambiguous virtual bases.
- (C++ only) Subscripting an array that has been declared `register`.
- (C++ only) Taking the address of a variable that has been declared `register`.
- (C++ only) A base class is not initialized in the copy constructor of a derived class.

`-Wabi` (C, Objective-C, C++ and Objective-C++ only)

Warn about code affected by ABI changes. This includes code that may not be compatible with the vendor-neutral C++ ABI as well as the psABI for the particular target. The latter warnings are also controlled separately by `-Wpsabi`, which is implied by `-Wabi`.

Since G++ now defaults to updating the ABI with each major release, normally `-Wabi` warns only about C++ ABI compatibility problems if there is a check added later in a release series for an ABI issue discovered since the initial release. `-Wabi` warns about more things if an older ABI version is selected (with `-fabi-version=n`).

`-Wabi` can also be used with an explicit version number to warn about C++ ABI compatibility with a particular `-fabi-version` level, e.g. `-Wabi=2` to warn about changes relative to `-fabi-version=2`.

If an explicit version number is provided and `-fabi-compat-version` is not specified, the version number from this option is used for compatibility aliases. If no explicit version number is provided with this option, but `-fabi-compat-version` is specified, that version number is used for C++ ABI warnings.

Although an effort has been made to warn about all such cases, there are probably some cases that are not warned about, even though G++ is generating incompatible code. There may also be cases where warnings are emitted even though the code that is generated is compatible.

You should rewrite your code to avoid these warnings if you are concerned about the fact that code generated by G++ may not be binary compatible with code generated by other compilers.

Known incompatibilities in `-fabi-version=2` (which was the default from GCC 3.4 to 4.9) include:

- A template with a non-type template parameter of reference type was mangled incorrectly:

  ```
  extern int N;
  template <int &> struct S {};
  void n (S<N>) {2}
  ```

  This was fixed in `-fabi-version=3`.

- SIMD vector types declared using `__attribute ((vector_size))` were mangled in a non-standard way that does not allow for overloading of functions taking vectors of different sizes.

  The mangling was changed in `-fabi-version=4`.

- `__attribute ((const))` and `noreturn` were mangled as type qualifiers, and `decltype` of a plain declaration was folded away.

  These mangling issues were fixed in `-fabi-version=5`.

- Scoped enumerators passed as arguments to a variadic function are promoted like unscoped enumerators, causing `va_arg` to complain. On most targets this does not actually affect the parameter passing ABI, as there is no way to pass an argument smaller than `int`.

  Also, the ABI changed the mangling of template argument packs, `const_cast`, `static_cast`, prefix increment/decrement, and a class scope function used as a template argument.

  These issues were corrected in `-fabi-version=6`.

- Lambdas in default argument scope were mangled incorrectly, and the ABI changed the mangling of `nullptr_t`.

  These issues were corrected in `-fabi-version=7`.

- When mangling a function type with function-cv-qualifiers, the un-qualified function type was incorrectly treated as a substitution candidate.

  This was fixed in `-fabi-version=8`, the default for GCC 5.1.

- `decltype(nullptr)` incorrectly had an alignment of 1, leading to unaligned accesses. Note that this did not affect the ABI of a function with a `nullptr_t` parameter, as parameters have a minimum alignment.

  This was fixed in `-fabi-version=9`, the default for GCC 5.2.

- Target-specific attributes that affect the identity of a type, such as ia32 calling conventions on a function type (stdcall, regparm, etc.), did not affect the mangled name, leading to name collisions when function pointers were used as template arguments.

  This was fixed in `-fabi-version=10`, the default for GCC 6.1.

`-Wpsabi` (C, Objective-C, C++ and Objective-C++ only)
: `-Wpsabi` enables warnings about processor-specific ABI changes, such as changes in alignment requirements or how function arguments are passed. On several targets, including AArch64, ARM, x86, MIPS, RS6000/PowerPC, and S/390, these details have changed between different versions of GCC and/or different versions of the C or C++ language standards in ways that affect binary compatibility of compiled code. With `-Wpsabi`, GCC can detect potentially incompatible usages and warn you about them.

  `-Wpsabi` is enabled by default, and is also implied by `-Wabi`.

`-Wno-changes-meaning` (C++ and Objective-C++ only)
: C++ requires that unqualified uses of a name within a class have the same meaning in the complete scope of the class, so declaring the name after using it is ill-formed:

```
struct A;
struct B1 { A a; typedef A A; }; // warning, 'A' changes meaning
struct B2 { A a; struct A { }; }; // error, 'A' changes meaning
```

  By default, the B1 case is only a warning because the two declarations have the same type, while the B2 case is an error. Both diagnostics can be disabled with `-Wno-changes-meaning`. Alternately, the error case can be reduced to a warning with `-Wno-error=changes-meaning` or `-fpermissive`.

  Both diagnostics are also suppressed by `-fms-extensions`.

`-Wchar-subscripts`
: Warn if an array subscript has type `char`. This is a common cause of error, as programmers often forget that this type is signed on some machines. This warning is enabled by `-Wall`.

`-Wno-coverage-mismatch`
: Warn if feedback profiles do not match when using the `-fprofile-use` option. If a source file is changed between compiling with `-fprofile-generate` and with `-fprofile-use`, the files with the profile feedback can fail to match the source file and GCC cannot use the profile feedback information. By default, this warning is enabled and is treated as an error. `-Wno-coverage-mismatch` can be used to disable the warning or `-Wno-error=coverage-mismatch` can be used to disable the error. Disabling the error for this warning can result in poorly optimized code and is useful only in the case of very minor changes such as bug fixes to an existing code-base. Completely disabling the warning is not recommended.

`-Wno-coverage-too-many-conditions`
: Warn if `-fcondition-coverage` is used and an expression have too many terms and GCC gives up coverage. Coverage is given up when there are more terms in the conditional than there are bits in a `gcov_type_unsigned`. This warning is enabled by default.

`-Wno-coverage-too-many-paths`
: Warn if `-fpath-coverage` is used and a function has too many paths and GCC gives up coverage. Giving up is controlled by `-fpath-coverage-limit`. This warning is enabled by default.

`-Wno-coverage-invalid-line-number`

Warn in case a function ends earlier than it begins due to an invalid linenum macros. The warning is emitted only with `--coverage` enabled.

By default, this warning is enabled and is treated as an error. `-Wno-coverage-invalid-line-number` can be used to disable the warning or `-Wno-error=coverage-invalid-line-number` can be used to disable the error.

`-Wno-cpp` (C, Objective-C, C++, Objective-C++ and Fortran only)

Suppress warning messages emitted by `#warning` directives.

`-Wdouble-promotion` (C, C++, Objective-C and Objective-C++ only)

Give a warning when a value of type `float` is implicitly promoted to `double`. CPUs with a 32-bit "single-precision" floating-point unit implement `float` in hardware, but emulate `double` in software. On such a machine, doing computations using `double` values is much more expensive because of the overhead required for software emulation.

It is easy to accidentally do computations with `double` because floating-point literals are implicitly of type `double`. For example, in:

```
float area(float radius)
{
   return 3.14159 * radius * radius;
}
```

the compiler performs the entire computation with `double` because the floating-point literal is a `double`.

`-Wduplicate-decl-specifier` (C and Objective-C only)

Warn if a declaration has duplicate `const`, `volatile`, `restrict` or `_Atomic` specifier. This warning is enabled by `-Wall`.

`-Wformat`
`-Wformat=`*n*

Check calls to `printf` and `scanf`, etc., to make sure that the arguments supplied have types appropriate to the format string specified, and that the conversions specified in the format string make sense. This includes standard functions, and others specified by format attributes (see Section 6.4.1 [Function Attributes], page 621), in the `printf`, `scanf`, `strftime` and `strfmon` (an X/Open extension, not in the C standard) families (or other target-specific families). Which functions are checked without format attributes having been specified depends on the standard version selected, and such checks of functions without the attribute specified are disabled by `-ffreestanding` or `-fno-builtin`.

The formats are checked against the format features supported by GNU libc version 2.2. These include all ISO C90 and C99 features, as well as features from the Single Unix Specification and some BSD and GNU extensions. Other library implementations may not support all these features; GCC does not support warning about features that go beyond a particular library's limitations. However, if `-Wpedantic` is used with `-Wformat`, warnings are given about format features not in the selected standard version (but not for `strfmon` formats, since those are not in any version of the C standard). See Section 3.4 [Options Controlling C Dialect], page 45.

`-Wformat=1`
`-Wformat`
: Option `-Wformat` is equivalent to `-Wformat=1`, and `-Wno-format` is equivalent to `-Wformat=0`. Since `-Wformat` also checks for null format arguments for several functions, `-Wformat` also implies `-Wnonnull`. Some aspects of this level of format checking can be disabled by the options: `-Wno-format-contains-nul`, `-Wno-format-diag`, `-Wno-format-extra-args`, and `-Wno-format-zero-length`. `-Wformat` is enabled by `-Wall`.

`-Wformat=2`
: Enable `-Wformat` plus additional format checks. Currently equivalent to `-Wformat -Wformat-nonliteral -Wformat-security -Wformat-y2k`.

`-Wno-format-contains-nul`
: If `-Wformat` is specified, do not warn about format strings that contain NUL bytes.

`-Wno-format-diag`
: If `-Wformat` is specified, do not warn about format strings that are unsuitable for GCC diagnostics.

`-Wno-format-extra-args`
: If `-Wformat` is specified, do not warn about excess arguments to a `printf` or `scanf` format function. The C standard specifies that such arguments are ignored.

Where the unused arguments lie between used arguments that are specified with '`$`' operand number specifications, normally warnings are still given, since the implementation could not know what type to pass to `va_arg` to skip the unused arguments. However, in the case of `scanf` formats, this option suppresses the warning if the unused arguments are all pointers, since the Single Unix Specification says that such unused arguments are allowed.

`-Wformat-overflow`
`-Wformat-overflow=`*level*
: Warn about calls to formatted input/output functions such as `sprintf` and `vsprintf` that might overflow the destination buffer. When the exact number of bytes written by a format directive cannot be determined at compile-time it is estimated based on heuristics that depend on the *level* argument and on optimization. While enabling optimization will in most cases improve the accuracy of the warning, it may also result in false positives.

`-Wformat-overflow`
`-Wformat-overflow=1`
: Level *1* of `-Wformat-overflow` enabled by `-Wformat` employs a conservative approach that warns only about calls that most likely overflow the buffer. At this level, numeric arguments to format directives with unknown values are assumed to have the value of one,

and strings of unknown length to be empty. Numeric arguments that are known to be bounded to a subrange of their type, or string arguments whose output is bounded either by their directive's precision or by a finite set of string literals, are assumed to take on the value within the range that results in the most bytes on output. For example, the call to `sprintf` below is diagnosed because even with both *a* and *b* equal to zero, the terminating NUL character (`'\0'`) appended by the function to the destination buffer will be written past its end. Increasing the size of the buffer by a single byte is sufficient to avoid the warning, though it may not be sufficient to avoid the overflow.

```
void f (int a, int b)
{
  char buf [13];
  sprintf (buf, "a = %i, b = %i\n", a, b);
}
```

`-Wformat-overflow=2`

Level *2* warns also about calls that might overflow the destination buffer given an argument of sufficient length or magnitude. At level *2*, unknown numeric arguments are assumed to have the minimum representable value for signed types with a precision greater than 1, and the maximum representable value otherwise. Unknown string arguments whose length cannot be assumed to be bounded either by the directive's precision, or by a finite set of string literals they may evaluate to, or the character array they may point to, are assumed to be 1 character long.

At level *2*, the call in the example above is again diagnosed, but this time because with *a* equal to a 32-bit `INT_MIN` the first `%i` directive will write some of its digits beyond the end of the destination buffer. To make the call safe regardless of the values of the two variables, the size of the destination buffer must be increased to at least 34 bytes. GCC includes the minimum size of the buffer in an informational note following the warning.

An alternative to increasing the size of the destination buffer is to constrain the range of formatted values. The maximum length of string arguments can be bounded by specifying the precision in the format directive. When numeric arguments of format directives can be assumed to be bounded by less than the precision of their type, choosing an appropriate length modifier to the format specifier will reduce the required buffer size. For example, if *a* and *b* in the example above can be assumed to be within the precision of the `short int` type then using either the `%hi` format directive or casting the argument to `short` reduces the maximum required size of the buffer to 24 bytes.

```
void f (int a, int b)
{
  char buf [23];
```

```
      sprintf (buf, "a = %hi, b = %i\n", a, (short)b);
    }
```

`-Wno-format-zero-length`
: If `-Wformat` is specified, do not warn about zero-length formats. The C standard specifies that zero-length formats are allowed.

`-Wformat-nonliteral`
: If `-Wformat` is specified, also warn if the format string is not a string literal and so cannot be checked, unless the format function takes its format arguments as a `va_list`.

`-Wformat-security`
: If `-Wformat` is specified, also warn about uses of format functions that represent possible security problems. At present, this warns about calls to `printf` and `scanf` functions where the format string is not a string literal and there are no format arguments, as in `printf (foo);`. This may be a security hole if the format string came from untrusted input and contains '`%n`'. (This is currently a subset of what `-Wformat-nonliteral` warns about, but in future warnings may be added to `-Wformat-security` that are not included in `-Wformat-nonliteral`.)

`-Wformat-signedness`
: If `-Wformat` is specified, also warn if the format string requires an unsigned argument and the argument is signed and vice versa.

`-Wformat-truncation`
`-Wformat-truncation=`*level*
: Warn about calls to formatted input/output functions such as `snprintf` and `vsnprintf` that might result in output truncation. When the exact number of bytes written by a format directive cannot be determined at compile-time it is estimated based on heuristics that depend on the *level* argument and on optimization. While enabling optimization will in most cases improve the accuracy of the warning, it may also result in false positives. Except as noted otherwise, the option uses the same logic `-Wformat-overflow`.

  `-Wformat-truncation`
  `-Wformat-truncation=1`
  : Level *1* of `-Wformat-truncation` enabled by `-Wformat` employs a conservative approach that warns only about calls to bounded functions whose return value is unused and that will most likely result in output truncation.

  `-Wformat-truncation=2`
  : Level *2* warns also about calls to bounded functions whose return value is used and that might result in truncation given an argument of sufficient length or magnitude.

`-Wformat-y2k`
: If `-Wformat` is specified, also warn about `strftime` formats that may yield only a two-digit year.

`-Wnonnull`

Warn about passing a null pointer for arguments marked as requiring a non-null value by the `nonnull` function attribute.

`-Wnonnull` is included in `-Wall` and `-Wformat`. It can be disabled with the `-Wno-nonnull` option.

`-Wnonnull-compare`

Warn when comparing an argument marked with the `nonnull` function attribute against null inside the function.

`-Wnonnull-compare` is included in `-Wall`. It can be disabled with the `-Wno-nonnull-compare` option.

`-Wnull-dereference`

Warn if the compiler detects paths that trigger erroneous or undefined behavior due to dereferencing a null pointer. This option is only active when `-fdelete-null-pointer-checks` is active, which is enabled by optimizations in most targets. The precision of the warnings depends on the optimization options used.

`-Wno-musttail-local-addr`

Do not warn about passing a pointer (or in C++, a reference) to a local variable or label to argument of a `musttail` call. Those variables go out of scope before the tail call instruction.

`-Wmaybe-musttail-local-addr`

Warn when address of a local variable can escape to a `musttail` call, unless it goes out of scope already before the `musttail` call.

```
int foo (int *);

int
bar (int *x)
{
  if (x[0] == 1)
    {
      int a = 42;
      foo (&a);
      /* Without the musttail attribute this call would not
         be tail called, because address of the a variable escapes
         and the second foo call could dereference it.  With the attribute
         the local variables are assumed to go out of scope immediately
         before the tail call instruction and the compiler warns about
         this.  */
      [[gnu::musttail]] return foo (nullptr);
    }
  else
    {
      {
        int a = 42;
        foo (&a);
      }
      /* The a variable isn't already in scope, so even when it
         escaped, even without musttail attribute it would be
         undefined behavior to dereference it and the compiler could
         turn this into a tail call.  No warning is diagnosed here.  */
```

```
      [[gnu::musttail]] return foo (nullptr);
    }
}
```

This warning is enabled by `-Wextra`.

`-Wnrvo` (C++ and Objective-C++ only)
: Warn if the compiler does not elide the copy from a local variable to the return value of a function in a context where it is allowed by [class.copy.elision]. This elision is commonly known as the Named Return Value Optimization. For instance, in the example below the compiler cannot elide copies from both v1 and v2, so it elides neither.

```
std::vector<int> f()
{
  std::vector<int> v1, v2;
  // ...
  if (cond) return v1;
  else return v2; // warning: not eliding copy
}
```

`-Winfinite-recursion`
: Warn about infinitely recursive calls. The warning is effective at all optimization levels but requires optimization in order to detect infinite recursion in calls between two or more functions. `-Winfinite-recursion` is included in `-Wall`.

Compare with `-Wanalyzer-infinite-recursion` which provides a similar diagnostic, but is implemented in a different way (as part of `-fanalyzer`).

`-Winit-self` (C, C++, Objective-C and Objective-C++ only)
: Warn about uninitialized variables that are initialized with themselves. Note this option can only be used with the `-Wuninitialized` option.

For example, GCC warns about `i` being uninitialized in the following snippet only when `-Winit-self` has been specified:

```
int f()
{
  int i = i;
  return i;
}
```

This warning is enabled by `-Wall` in C++.

`-Wno-implicit-int` (C and Objective-C only)
: This option controls warnings when a declaration does not specify a type. This warning is enabled by default, as an error, in C99 and later dialects of C, and also by `-Wall`. The error can be downgraded to a warning using `-fpermissive` (along with certain other errors), or for this error alone, with `-Wno-error=implicit-int`.

This warning is upgraded to an error by `-pedantic-errors`.

`-Wno-implicit-function-declaration` (C and Objective-C only)
: This option controls warnings when a function is used before being declared. This warning is enabled by default, as an error, in C99 and later dialects of C, and also by `-Wall`. The error can be downgraded to a warning using `-fpermissive` (along with certain other errors), or for this error alone, with `-Wno-error=implicit-function-declaration`.

This warning is upgraded to an error by `-pedantic-errors`.

`-Wimplicit` (C and Objective-C only)
: Same as `-Wimplicit-int` and `-Wimplicit-function-declaration`. This warning is enabled by `-Wall`.

`-Whardened`
: Warn when `-fhardened` did not enable an option from its set (for which see `-fhardened`). For instance, using `-fhardened` and `-fstack-protector` at the same time on the command line causes `-Whardened` to warn because `-fstack-protector-strong` will not be enabled by `-fhardened`.

This warning is enabled by default and has effect only when `-fhardened` is enabled.

`-Wimplicit-fallthrough`
: `-Wimplicit-fallthrough` is the same as `-Wimplicit-fallthrough=3` and `-Wno-implicit-fallthrough` is the same as `-Wimplicit-fallthrough=0`.

`-Wimplicit-fallthrough=`*n*
: Warn when a switch case falls through. For example:

```
switch (cond)
  {
  case 1:
    a = 1;
    break;
  case 2:
    a = 2;
  case 3:
    a = 3;
    break;
  }
```

This warning does not warn when the last statement of a case cannot fall through, e.g. when there is a return statement or a call to function declared with the noreturn attribute. `-Wimplicit-fallthrough=` also takes into account control flow statements, such as ifs, and only warns when appropriate. E.g.

```
switch (cond)
  {
  case 1:
    if (i > 3) {
      bar (5);
      break;
    } else if (i < 1) {
      bar (0);
    } else
      return;
  default:
    ...
  }
```

Since there are occasions where a switch case fall through is desirable, GCC provides an attribute, `__attribute__ ((fallthrough))`, that is to be used along with a null statement to suppress this warning that would normally occur:

```
switch (cond)
  {
  case 1:
    bar (0);
    __attribute__ ((fallthrough));
  default:
    ...
  }
```

C++17 and C23 provide a standard way to suppress the `-Wimplicit-fallthrough` warning using `[[fallthrough]];` instead of the GNU attribute. In C++11 or C++14 users can use `[[gnu::fallthrough]];`, which is a GNU extension. Instead of these attributes, it is also possible to add a fallthrough comment to silence the warning. The whole body of the C or C++ style comment should match the given regular expressions listed below. The option argument *n* specifies what kind of comments are accepted:

- `-Wimplicit-fallthrough=0` disables the warning altogether.
- `-Wimplicit-fallthrough=1` matches `.*` regular expression, any comment is used as fallthrough comment.
- `-Wimplicit-fallthrough=2` case insensitively matches `.*falls?[ \t-]*thr(ough|u).*` regular expression.
- `-Wimplicit-fallthrough=3` case sensitively matches one of the following regular expressions:
  - `-fallthrough`
  - `@fallthrough@`
  - `lint -fallthrough[ \t]*`
  - `[ \t.!]*(ELSE,? |INTENTIONAL(LY)? )?FALL(S | |-)?THR(OUGH|U)[ \t.!]*(-[^\n\r]*)?`
  - `[ \t.!]*(Else,? |Intentional(ly)? )?Fall((s | |-)[Tt]|t)hr(ough|u)[ \t.!]*(-[^\n\r]*)?`
  - `[ \t.!]*([Ee]lse,? |[Ii]ntentional(ly)? )?fall(s | |-)?thr(ough|u)[ \t.!]*(-[^\n\r]*)?`
- `-Wimplicit-fallthrough=4` case sensitively matches one of the following regular expressions:
  - `-fallthrough`
  - `@fallthrough@`
  - `lint -fallthrough[ \t]*`
  - `[ \t]*FALLTHR(OUGH|U)[ \t]*`
- `-Wimplicit-fallthrough=5` doesn't recognize any comments as fallthrough comments, only attributes disable the warning.

The comment needs to be followed after optional whitespace and other comments by `case` or `default` keywords or by a user label that precedes some `case` or `default` label.

```
switch (cond)
  {
  case 1:
    bar (0);
    /* FALLTHRU */
  default:
    ...
  }
```

The `-Wimplicit-fallthrough=3` warning is enabled by `-Wextra`.

`-Wno-if-not-aligned` (C, C++, Objective-C and Objective-C++ only)
: Control if warnings triggered by the `warn_if_not_aligned` attribute should be issued. These warnings are enabled by default.

`-Wignored-qualifiers` (C and C++ only)
: Warn if the return type of a function has a type qualifier such as `const`. For ISO C such a type qualifier has no effect, since the value returned by a function is not an lvalue. For C++, the warning is only emitted for scalar types or `void`. ISO C prohibits qualified `void` return types on function definitions, so such return types always receive a warning even without this option.

This warning is also enabled by `-Wextra`.

`-Wno-ignored-attributes` (C and C++ only)
: This option controls warnings when an attribute is ignored. This is different from the `-Wattributes` option in that it warns whenever the compiler decides to drop an attribute, not that the attribute is either unknown, used in a wrong place, etc. This warning is enabled by default.

`-Wmain`
: Warn if the type of `main` is suspicious. `main` should be a function with external linkage, returning int, taking either zero arguments, two, or three arguments of appropriate types. This warning is enabled by default in C++ and is enabled by either `-Wall` or `-Wpedantic`.

This warning is upgraded to an error by `-pedantic-errors`.

`-Wmisleading-indentation` (C and C++ only)
: Warn when the indentation of the code does not reflect the block structure. Specifically, a warning is issued for `if`, `else`, `while`, and `for` clauses with a guarded statement that does not use braces, followed by an unguarded statement with the same indentation.

In the following example, the call to “bar” is misleadingly indented as if it were guarded by the “if” conditional.

```
if (some_condition ())
  foo ();
  bar ();  /* Gotcha: this is not guarded by the "if".  */
```

In the case of mixed tabs and spaces, the warning uses the `-ftabstop=` option to determine if the statements line up (defaulting to 8).

The warning is not issued for code involving multiline preprocessor logic such as the following example.

```
if (flagA)
  foo (0);
```

```
#if SOME_CONDITION_THAT_DOES_NOT_HOLD
  if (flagB)
#endif
    foo (1);
```

The warning is not issued after a `#line` directive, since this typically indicates autogenerated code, and no assumptions can be made about the layout of the file that the directive references.

This warning is enabled by `-Wall` in C and C++.

`-Wmissing-attributes`

Warn when a declaration of a function is missing one or more attributes that a related function is declared with and whose absence may adversely affect the correctness or efficiency of generated code. For example, the warning is issued for declarations of aliases that use attributes to specify less restrictive requirements than those of their targets. This typically represents a potential optimization opportunity. By contrast, the `-Wattribute-alias=2` option controls warnings issued when the alias is more restrictive than the target, which could lead to incorrect code generation. Attributes considered include `alloc_align`, `alloc_size`, `cold`, `const`, `hot`, `leaf`, `malloc`, `nonnull`, `noreturn`, `nothrow`, `pure`, `returns_nonnull`, and `returns_twice`.

In C++, the warning is issued when an explicit specialization of a primary template declared with attribute `alloc_align`, `alloc_size`, `assume_aligned`, `format`, `format_arg`, `malloc`, or `nonnull` is declared without it. Attributes `deprecated`, `error`, and `warning` suppress the warning. (see Section 6.4.1 [Function Attributes], page 621).

You can use the `copy` attribute to apply the same set of attributes to a declaration as that on another declaration without explicitly enumerating the attributes. This attribute can be applied to declarations of functions (see Section 6.4.1.1 [Common Function Attributes], page 622), variables (see Section 6.4.2.1 [Common Variable Attributes], page 699), or types (see Section 6.4.3.1 [Common Type Attributes], page 715).

`-Wmissing-attributes` is enabled by `-Wall`.

For example, since the declaration of the primary function template below makes use of both attribute `malloc` and `alloc_size` the declaration of the explicit specialization of the template is diagnosed because it is missing one of the attributes.

```
template <class T>
T* __attribute__ ((malloc, alloc_size (1)))
allocate (size_t);

template <>
void* __attribute__ ((malloc))   // missing alloc_size
allocate<void> (size_t);
```

`-Wmissing-braces`

Warn if an aggregate or union initializer is not fully bracketed. In the following example, the initializer for `a` is not fully bracketed, but that for `b` is fully bracketed.

```
int a[2][2] = { 0, 1, 2, 3 };
```

```
int b[2][2] = { { 0, 1 }, { 2, 3 } };
```

This warning is enabled by `-Wall`.

`-Wmissing-include-dirs` (C, C++, Objective-C, Objective-C++ and Fortran only)
: Warn if a user-supplied include directory does not exist. This option is disabled by default for C, C++, Objective-C and Objective-C++. For Fortran, it is partially enabled by default by warning for -I and -J, only.

`-Wno-missing-profile`
: This option controls warnings if feedback profiles are missing when using the `-fprofile-use` option. This option diagnoses those cases where a new function or a new file is added between compiling with `-fprofile-generate` and with `-fprofile-use`, without regenerating the profiles. In these cases, the profile feedback data files do not contain any profile feedback information for the newly added function or file respectively. Also, in the case when profile count data (.gcda) files are removed, GCC cannot use any profile feedback information. In all these cases, warnings are issued to inform you that a profile generation step is due. Ignoring the warning can result in poorly optimized code. `-Wno-missing-profile` can be used to disable the warning, but this is not recommended and should be done only when non-existent profile data is justified.

`-Wmismatched-dealloc`
: Warn for calls to deallocation functions with pointer arguments returned from allocation functions for which the former isn't a suitable deallocator. A pair of functions can be associated as matching allocators and deallocators by use of attribute `malloc`. Unless disabled by the `-fno-builtin` option the standard functions `calloc`, `malloc`, `realloc`, and `free`, as well as the corresponding forms of C++ `operator new` and `operator delete` are implicitly associated as matching allocators and deallocators. In the following example `mydealloc` is the deallocator for pointers returned from `myalloc`.

```
void mydealloc (void*);

__attribute__ ((malloc (mydealloc, 1))) void*
myalloc (size_t);

void f (void)
{
  void *p = myalloc (32);
  // ...use p...
  free (p);   // warning: not a matching deallocator for myalloc
  mydealloc (p);   // ok
}
```

In C++, the related option `-Wmismatched-new-delete` diagnoses mismatches involving either `operator new` or `operator delete`.

Option `-Wmismatched-dealloc` is included in `-Wall`.

`-Wmultistatement-macros`
: Warn about unsafe multiple statement macros that appear to be guarded by a clause such as `if`, `else`, `for`, `switch`, or `while`, in which only the first statement is actually guarded after the macro is expanded.

For example:

```
#define DOIT x++; y++
if (c)
  DOIT;
```

will increment `y` unconditionally, not just when `c` holds. The can usually be fixed by wrapping the macro in a do-while loop:

```
#define DOIT do { x++; y++; } while (0)
if (c)
  DOIT;
```

This warning is enabled by `-Wall` in C and C++.

`-Wparentheses`

Warn if parentheses are omitted in certain contexts, such as when there is an assignment in a context where a truth value is expected, or when operators are nested whose precedence people often get confused about.

Also warn if a comparison like `x<=y<=z` appears; this is equivalent to `(x<=y ? 1 : 0) <= z`, which is a different interpretation from that of ordinary mathematical notation.

Also warn for dangerous uses of the GNU extension to `?:` with omitted middle operand. When the condition in the `?`: operator is a boolean expression, the omitted value is always 1. Often programmers expect it to be a value computed inside the conditional expression instead.

For C++ this also warns for some cases of unnecessary parentheses in declarations, which can indicate an attempt at a function call instead of a declaration:

```
{
  // Declares a local variable called mymutex.
  std::unique_lock<std::mutex> (mymutex);
  // User meant std::unique_lock<std::mutex> lock (mymutex);
}
```

This warning is enabled by `-Wall`.

`-Wno-self-move` (C++ and Objective-C++ only)

This warning warns when a value is moved to itself with `std::move`. Such a `std::move` typically has no effect.

```
struct T {
...
};
void fn()
{
  T t;
  ...
  t = std::move (t);
}
```

This warning is enabled by `-Wall`.

`-Wsequence-point`

Warn about code that may have undefined semantics because of violations of sequence point rules in the C and C++ standards.

The C and C++ standards define the order in which expressions in a C/C++ program are evaluated in terms of *sequence points*, which represent a partial ordering between the execution of parts of the program: those executed before the sequence point, and those executed after it. These occur after the evaluation of a full expression (one which is not part of a larger expression), after the evaluation of the first operand of a `&&`, `||`, `? :` or `,` (comma) operator, before a function is called (but after the evaluation of its arguments and the expression denoting the called function), and in certain other places. Other than as expressed by the sequence point rules, the order of evaluation of subexpressions of an expression is not specified. All these rules describe only a partial order rather than a total order, since, for example, if two functions are called within one expression with no sequence point between them, the order in which the functions are called is not specified. However, the standards committee have ruled that function calls do not overlap.

It is not specified when between sequence points modifications to the values of objects take effect. Programs whose behavior depends on this have undefined behavior; the C and C++ standards specify that "Between the previous and next sequence point an object shall have its stored value modified at most once by the evaluation of an expression. Furthermore, the prior value shall be read only to determine the value to be stored.". If a program breaks these rules, the results on any particular implementation are entirely unpredictable.

Examples of code with undefined behavior are `a = a++;`, `a[n] = b[n++]` and `a[i++] = i;`. Some more complicated cases are not diagnosed by this option, and it may give an occasional false positive result, but in general it has been found fairly effective at detecting this sort of problem in programs.

The C++17 standard will define the order of evaluation of operands in more cases: in particular it requires that the right-hand side of an assignment be evaluated before the left-hand side, so the above examples are no longer undefined. But this option will still warn about them, to help people avoid writing code that is undefined in C and earlier revisions of C++.

The standard is worded confusingly, therefore there is some debate over the precise meaning of the sequence point rules in subtle cases. Links to discussions of the problem, including proposed formal definitions, may be found on the GCC readings page, at `https://gcc.gnu.org/readings.html`.

This warning is enabled by `-Wall` for C and C++.

`-Wno-return-local-addr`

Do not warn about returning a pointer (or in C++, a reference) to a variable that goes out of scope after the function returns.

`-Wreturn-mismatch`

Warn about return statements without an expressions in functions which do not return `void`. Also warn about a `return` statement with an expression in a function whose return type is `void`, unless the expression type is also `void`. As a GNU extension, the latter case is accepted without a warning unless `-Wpedantic` is used.

Attempting to use the return value of a non-`void` function other than `main` that flows off the end by reaching the closing curly brace that terminates the function is undefined.

This warning is specific to C and enabled by default. In C99 and later language dialects, it is treated as an error. It can be downgraded to a warning using `-fpermissive` (along with other warnings), or for just this warning, with `-Wno-error=return-mismatch`.

`-Wreturn-type`
: Warn whenever a function is defined with a return type that defaults to `int` (unless `-Wimplicit-int` is active, which takes precedence). Also warn if execution may reach the end of the function body, or if the function does not contain any return statement at all.

  Attempting to use the return value of a non-`void` function other than `main` that flows off the end by reaching the closing curly brace that terminates the function is undefined.

  Unlike in C, in C++, flowing off the end of a non-`void` function other than `main` results in undefined behavior even when the value of the function is not used.

  This warning is enabled by default in C++ and by `-Wall` otherwise.

`-Wno-shift-count-negative`
: Controls warnings if a shift count is negative. This warning is enabled by default.

`-Wno-shift-count-overflow`
: Controls warnings if a shift count is greater than or equal to the bit width of the type. This warning is enabled by default.

`-Wshift-negative-value`
: Warn if left shifting a negative value. This warning is enabled by `-Wextra` in C99 (and newer) and C++11 to C++17 modes.

`-Wno-shift-overflow`
`-Wshift-overflow=n`
: These options control warnings about left shift overflows.

  `-Wshift-overflow=1`
  : This is the warning level of `-Wshift-overflow` and is enabled by default in C99 and C++11 modes (and newer). This warning level does not warn about left-shifting 1 into the sign bit. (However, in C, such an overflow is still rejected in contexts where an integer constant expression is required.) No warning is emitted in C++20 mode (and newer), as signed left shifts always wrap.

  `-Wshift-overflow=2`
  : This warning level also warns about left-shifting 1 into the sign bit, unless C++14 mode (or newer) is active.

`-Wswitch`
: Warn whenever a `switch` statement has an index of enumerated type and lacks a `case` for one or more of the named codes of that enumeration. (The presence of a `default` label prevents this warning.) `case` labels that do not correspond to enumerators also provoke warnings when this option is used, unless the enumeration is marked with the `flag_enum` attribute. This warning is enabled by `-Wall`.

`-Wswitch-default`
Warn whenever a `switch` statement does not have a `default` case.

`-Wswitch-enum`
Warn whenever a `switch` statement has an index of enumerated type and lacks a `case` for one or more of the named codes of that enumeration. `case` labels that do not correspond to enumerators also provoke warnings when this option is used, unless the enumeration is marked with the `flag_enum` attribute. The only difference between `-Wswitch` and this option is that this option gives a warning about an omitted enumeration code even if there is a `default` label.

`-Wno-switch-bool`
Do not warn when a `switch` statement has an index of boolean type and the case values are outside the range of a boolean type. It is possible to suppress this warning by casting the controlling expression to a type other than `bool`. For example:

```
switch ((int) (a == 4))
  {
  ...
  }
```

This warning is enabled by default for C and C++ programs.

`-Wno-switch-outside-range`
This option controls warnings when a `switch` case has a value that is outside of its respective type range. This warning is enabled by default for C and C++ programs.

`-Wno-switch-unreachable`
Do not warn when a `switch` statement contains statements between the controlling expression and the first case label, which will never be executed. For example:

```
switch (cond)
  {
   i = 15;
  ...
   case 5:
  ...
  }
```

`-Wswitch-unreachable` does not warn if the statement between the controlling expression and the first case label is just a declaration:

```
switch (cond)
  {
   int i;
  ...
   case 5:
   i = 5;
  ...
  }
```

This warning is enabled by default for C and C++ programs.

`-Wsync-nand` (C and C++ only)
Warn when `__sync_fetch_and_nand` and `__sync_nand_and_fetch` built-in functions are used. These functions changed semantics in GCC 4.4.

`-Wtrivial-auto-var-init`

Warn when `-ftrivial-auto-var-init` cannot initialize the automatic variable. A common situation is an automatic variable that is declared between the controlling expression and the first case label of a `switch` statement.

`-Wunused-but-set-parameter`

`-Wunused-but-set-parameter` is the same as `-Wunused-but-set-parameter=3` and `-Wno-unused-but-set-parameter` is the same as `-Wunused-but-set-parameter=0`.

`-Wunused-but-set-parameter=`*n*

Warn whenever a function parameter is assigned to, but otherwise unused (aside from its declaration).

To suppress this warning use the `unused` attribute (see Section 6.4.2 [Variable Attributes], page 699).

`-Wunused-but-set-parameter=0` disables the warning. With `-Wunused-but-set-parameter=1` all uses except initialization and left hand side of assignment which is not further used disable the warning. With `-Wunused-but-set-parameter=2` additionally uses of parameter in `++` and `--` operators don't count as uses. And finally with `-Wunused-but-set-parameter=3` additionally uses in *parm* `@=` *rhs* outside of *rhs* don't count as uses. See `-Wunused-but-set-variable=`*n* option for examples.

This `-Wunused-but-set-parameter=3` warning is also enabled by `-Wunused` together with `-Wextra`.

`-Wunused-but-set-variable`

`-Wunused-but-set-variable` is the same as `-Wunused-but-set-variable=3` and `-Wno-unused-but-set-variable` is the same as `-Wunused-but-set-variable=0`.

`-Wunused-but-set-variable=`*n*

Warn whenever a local variable is assigned to, but otherwise unused (aside from its declaration). This `-Wunused-but-set-variable=3` warning is enabled by `-Wall`.

To suppress this warning use the `unused` attribute (see Section 6.4.2 [Variable Attributes], page 699).

`-Wunused-but-set-variable=0` disables the warning. With `-Wunused-but-set-variable=1` all uses except initialization and left hand side of assignment which is not further used disable the warning. With `-Wunused-but-set-variable=2` additionally uses of variable in `++` and `--` operators don't count as uses. And finally with `-Wunused-but-set-variable=3` additionally uses in *parm* `@=` *rhs* outside of *rhs* don't count as uses.

This `-Wunused-but-set-variable=3` warning is also enabled by `-Wunused`, which is enabled by `-Wall`.

```
void foo (void)
{
  int a = 1; // -Wunused-variable warning
  int b = 0; // Warning for n >= 1
  b = 1; b = 2;
```

```
    int c = 0; // Warning for n >= 2
    ++c; c--; --c; c++;
    int d = 0; // Warning for n >= 3
    d += 4;
    int e = 0; // No warning, cast to void
    (void) e;
    int f = 0; // No warning, f used
    int g = f = 5;
    (void) g;
    int h = 0; // No warning, preincrement used
    int i = ++h;
    (void) i;
    int j = 0; // No warning, postdecrement used
    int k = j--;
    (void) k;
    int l = 0; // No warning, l used
    int m = l |= 2;
    (void) m;
  }
```

`-Wunused-function`
: Warn whenever a static function is declared but not defined or a non-inline static function is unused. This warning is enabled by `-Wall`.

`-Wunused-label`
: Warn whenever a label is declared but not used. This warning is enabled by `-Wall`.

  To suppress this warning use the `unused` attribute (see Section 6.4.2 [Variable Attributes], page 699).

`-Wunused-local-typedefs` (C, Objective-C, C++ and Objective-C++ only)
: Warn when a typedef locally defined in a function is not used. This warning is enabled by `-Wall`.

`-Wunused-parameter`
: Warn whenever a function parameter is unused aside from its declaration. This option is not enabled by `-Wunused` unless `-Wextra` is also specified.

  To suppress this warning use the `unused` attribute (see Section 6.4.2 [Variable Attributes], page 699).

`-Wno-unused-result`
: Do not warn if a caller of a function marked with attribute `warn_unused_result` (see Section 6.4.1 [Function Attributes], page 621) does not use its return value. The default is `-Wunused-result`.

`-Wunused-variable`
: Warn whenever a local or static variable is unused aside from its declaration. This option implies `-Wunused-const-variable=1` for C, but not for C++. This warning is enabled by `-Wall`.

  To suppress this warning use the `unused` attribute (see Section 6.4.2 [Variable Attributes], page 699).

`-Wunused-const-variable`
`-Wunused-const-variable=`*n*
: Warn whenever a constant static variable is unused aside from its declaration.

To suppress this warning use the `unused` attribute (see Section 6.4.2 [Variable Attributes], page 699).

`-Wunused-const-variable=1`
: Warn about unused static const variables defined in the main compilation unit, but not about static const variables declared in any header included.

  `-Wunused-const-variable=1` is enabled by either `-Wunused-variable` or `-Wunused` for C, but not for C++. In C this declares variable storage, but in C++ this is not an error since const variables take the place of `#define`s.

`-Wunused-const-variable=2`
: This warning level also warns for unused constant static variables in headers (excluding system headers). It is equivalent to the short form `-Wunused-const-variable`. This level must be explicitly requested in both C and C++ because it might be hard to clean up all headers included.

`-Wunused-value`
: Warn whenever a statement computes a result that is explicitly not used. To suppress this warning cast the unused expression to `void`. This includes an expression-statement or the left-hand side of a comma expression that contains no side effects. For example, an expression such as `x[i,j]` causes a warning, while `x[(void)i,j]` does not.

  This warning is enabled by `-Wall`.

`-Wunused`
: All the above `-Wunused` options combined, except those documented as needing to be specified explicitly.

  In order to get a warning about an unused function parameter, you must either specify `-Wextra -Wunused` (note that `-Wall` implies `-Wunused`), or separately specify `-Wunused-parameter` and/or `-Wunused-but-set-parameter`.

  `-Wunused` enables only `-Wunused-const-variable=1` rather than `-Wunused-const-variable`, and only for C, not C++.

`-Wuse-after-free` (C, Objective-C, C++ and Objective-C++ only)
`-Wuse-after-free=`*n*
: Warn about uses of pointers to dynamically allocated objects that have been rendered indeterminate by a call to a deallocation function. The warning is enabled at all optimization levels but may yield different results with optimization than without.

  `-Wuse-after-free=1`
  : At level 1 the warning attempts to diagnose only unconditional uses of pointers made indeterminate by a deallocation call or a successful call to `realloc`, regardless of whether or not the call resulted in an actual reallocation of memory. This includes double-`free` calls as well as uses in arithmetic and relational expressions. Although undefined, uses of indeterminate pointers in equality (or inequality) expressions are not diagnosed at this level.

`-Wuse-after-free=2`

At level 2, in addition to unconditional uses, the warning also diagnoses conditional uses of pointers made indeterminate by a deallocation call. As at level 2, uses in equality (or inequality) expressions are not diagnosed. For example, the second call to `free` in the following function is diagnosed at this level:

```
struct A { int refcount; void *data; };

void release (struct A *p)
{
  int refcount = --p->refcount;
  free (p);
  if (refcount == 0)
    free (p->data);   // warning: p may be used after free
}
```

`-Wuse-after-free=3`

At level 3, the warning also diagnoses uses of indeterminate pointers in equality expressions. All uses of indeterminate pointers are undefined but equality tests sometimes appear after calls to `realloc` as an attempt to determine whether the call resulted in relocating the object to a different address. They are diagnosed at a separate level to aid gradually transitioning legacy code to safe alternatives. For example, the equality test in the function below is diagnosed at this level:

```
void adjust_pointers (int**, int);

void grow (int **p, int n)
{
  int **q = (int**)realloc (p, n *= 2);
  if (q == p)
    return;
  adjust_pointers ((int**)q, n);
}
```

To avoid the warning at this level, store offsets into allocated memory instead of pointers. This approach obviates needing to adjust the stored pointers after reallocation.

`-Wuse-after-free=2` is included in `-Wall`.

`-Wuseless-cast` (C, Objective-C, C++ and Objective-C++ only)

Warn when an expression is cast to its own type. This warning does not occur when a class object is converted to a non-reference type as that is a way to create a temporary:

```
struct S { };
void g (S&&);
void f (S&& arg)
{
  g (S(arg)); // make arg prvalue so that it can bind to S&&
}
```

`-Wuninitialized`

Warn if an object with automatic or allocated storage duration is used without having been initialized. In C++, also warn if a non-static reference or non-static `const` member appears in a class without constructors.

In addition, passing a pointer (or in C++, a reference) to an uninitialized object to a `const`-qualified argument of a built-in function known to read the object is also diagnosed by this warning. (`-Wmaybe-uninitialized` is issued for ordinary functions.)

If you want to warn about code that uses the uninitialized value of the variable in its own initializer, use the `-Winit-self` option.

These warnings occur for individual uninitialized elements of structure, union or array variables as well as for variables that are uninitialized as a whole. They do not occur for variables or elements declared `volatile`. Because these warnings depend on optimization, the exact variables or elements for which there are warnings depend on the precise optimization options and version of GCC used.

Note that there may be no warning about a variable that is used only to compute a value that itself is never used, because such computations may be deleted by data flow analysis before the warnings are printed.

In C++, this warning also warns about using uninitialized objects in member-initializer-lists. For example, GCC warns about `b` being uninitialized in the following snippet:

```
struct A {
  int a;
  int b;
  A() : a(b) { }
};
```

`-Wno-invalid-memory-model`

This option controls warnings for invocations of Section 7.9.1 [__atomic Builtins], page 854, Section 7.9.2 [__sync Builtins], page 859, and the C11 atomic generic functions with a memory consistency argument that is either invalid for the operation or outside the range of values of the `memory_order` enumeration. For example, since the `__atomic_store` and `__atomic_store_n` built-ins are only defined for the relaxed, release, and sequentially consistent memory orders the following code is diagnosed:

```
void store (int *i)
{
  __atomic_store_n (i, 0, memory_order_consume);
}
```

`-Winvalid-memory-model` is enabled by default.

`-Wmaybe-uninitialized`

For an object with automatic or allocated storage duration, if there exists a path from the function entry to a use of the object that is initialized, but there exist some other paths for which the object is not initialized, the compiler emits a warning if it cannot prove the uninitialized paths are not executed at run time.

In addition, passing a pointer (or in C++, a reference) to an uninitialized object to a `const`-qualified function argument is also diagnosed by this warning. (`-Wuninitialized` is issued for built-in functions known to read the object.) Annotating the function with attribute `access (none)` indicates that the argument isn't used to access the object and avoids the warning (see Section 6.4.1.1 [Common Function Attributes], page 622).

These warnings are only possible in optimizing compilation, because otherwise GCC does not keep track of the state of variables. On the other hand, `-Wmaybe-uninitialized` is known not to warn in many situations (false negatives) due to optimizations taking advantage of undefinedness of uninitialized uses like constant propagation.

These warnings are made optional because GCC may not be able to determine when the code is correct in spite of appearing to have an error. Here is one example of how this can happen:

```
{
  int x;
  switch (y)
    {
    case 1: x = 1;
      break;
    case 2: x = 4;
      break;
    case 3: x = 5;
    }
  foo (x);
}
```

If the value of `y` is always 1, 2 or 3, then `x` is always initialized, but GCC doesn't know this. To suppress the warning, you need to provide a default case with assert(0) or similar code.

This option also warns when a non-volatile automatic variable might be changed by a call to `longjmp`. The compiler sees only the calls to `setjmp`. It cannot know where `longjmp` will be called; in fact, a signal handler could call it at any point in the code. As a result, you may get a warning even when there is in fact no problem because `longjmp` cannot in fact be called at the place that would cause a problem.

Some spurious warnings can be avoided if you declare all the functions you use that never return as `noreturn`. See Section 6.4.1 [Function Attributes], page 621.

This warning is enabled by `-Wall` or `-Wextra`.

`-Wunknown-pragmas`

Warn when a `#pragma` directive is encountered that is not understood by GCC. If this command-line option is used, warnings are even issued for unknown pragmas in system header files. This is not the case if the warnings are only enabled by the `-Wall` command-line option.

`-Wno-pragmas`

Do not warn about misuses of pragmas, such as incorrect parameters, invalid syntax, or conflicts between pragmas. See also `-Wunknown-pragmas`.

`-Wno-pragma-once-outside-header`

Do not warn when `#pragma once` is used in a file that is not a header file, such as a main file.

`-Wno-prio-ctor-dtor`

Do not warn if a priority from 0 to 100 is used for constructor or destructor. The use of constructor and destructor attributes allow you to assign a priority to the constructor/destructor to control its order of execution before `main` is called or after it returns. The priority values must be greater than 100 as the compiler reserves priority values between 0–100 for the implementation.

`-Wstrict-aliasing`

This option is only active when `-fstrict-aliasing` is active. It warns about code that might break the strict aliasing rules that the compiler is using for optimization. The warning does not catch all cases, but does attempt to catch the more common pitfalls. It is included in `-Wall`. It is equivalent to `-Wstrict-aliasing=3`.

`-Wstrict-aliasing=`*n*

This option is only active when `-fstrict-aliasing` is active. It warns about code that might break the strict aliasing rules that the compiler is using for optimization. Higher levels correspond to higher accuracy (fewer false positives). Higher levels also correspond to more effort, similar to the way `-O` works. `-Wstrict-aliasing` is equivalent to `-Wstrict-aliasing=3`.

Level 1: Most aggressive, quick, least accurate. Possibly useful when higher levels do not warn but `-fstrict-aliasing` still breaks the code, as it has very few false negatives. However, it has many false positives. Warns for all pointer conversions between possibly incompatible types, even if never dereferenced. Runs in the front end only.

Level 2: Aggressive, quick, not too precise. May still have many false positives (not as many as level 1 though), and few false negatives (but possibly more than level 1). Unlike level 1, it only warns when an address is taken. Warns about incomplete types. Runs in the front end only.

Level 3 (default for `-Wstrict-aliasing`): Should have very few false positives and few false negatives. Slightly slower than levels 1 or 2 when optimization is enabled. Takes care of the common pun+dereference pattern in the front end: `*(int*)&some_float`. If optimization is enabled, it also runs in the back end, where it deals with multiple statement cases using flow-sensitive points-to information. Only warns when the converted pointer is dereferenced. Does not warn about incomplete types.

`-Wstrict-overflow`
`-Wstrict-overflow=`*n*

This option is only active when signed overflow is undefined. It warns about cases where the compiler optimizes based on the assumption that signed overflow does not occur. Note that it does not warn about all cases where the code might overflow: it only warns about cases where the compiler implements some optimization. Thus this warning depends on the optimization level.

An optimization that assumes that signed overflow does not occur is perfectly safe if the values of the variables involved are such that overflow never does, in fact, occur. Therefore this warning can easily give a false positive: a warning about code that is not actually a problem. To help focus on important issues, several warning levels are defined. No warnings are issued for the use of undefined signed overflow when estimating how many iterations a loop requires, in particular when determining whether a loop will be executed at all.

`-Wstrict-overflow=1`
: Warn about cases that are both questionable and easy to avoid. For example the compiler simplifies `x + 1 > x` to `1`. This level of `-Wstrict-overflow` is enabled by `-Wall`; higher levels are not, and must be explicitly requested.

`-Wstrict-overflow=2`
: Also warn about other cases where a comparison is simplified to a constant. For example: `abs (x) >= 0`. This can only be simplified when signed integer overflow is undefined, because `abs (INT_MIN)` overflows to `INT_MIN`, which is less than zero. `-Wstrict-overflow` (with no level) is the same as `-Wstrict-overflow=2`.

`-Wstrict-overflow=3`
: Also warn about other cases where a comparison is simplified. For example: `x + 1 > 1` is simplified to `x > 0`.

`-Wstrict-overflow=4`
: Also warn about other simplifications not covered by the above cases. For example: `(x * 10) / 5` is simplified to `x * 2`.

`-Wstrict-overflow=5`
: Also warn about cases where the compiler reduces the magnitude of a constant involved in a comparison. For example: `x + 2 > y` is simplified to `x + 1 >= y`. This is reported only at the highest warning level because this simplification applies to many comparisons, so this warning level gives a very large number of false positives.

`-Wstring-compare`
: Warn for calls to `strcmp` and `strncmp` whose result is determined to be either zero or non-zero in tests for such equality owing to the length of one argument being greater than the size of the array the other argument is stored in (or the bound in the case of `strncmp`). Such calls could be mistakes. For example, the call to `strcmp` below is diagnosed because its result is necessarily non-zero irrespective of the contents of the array `a`.

```
extern char a[4];
void f (char *d)
{
  strcpy (d, "string");
  ...
  if (0 == strcmp (a, d))   // cannot be true
    puts ("a and d are the same");
}
```

`-Wstring-compare` is enabled by `-Wextra`.

-Wno-stringop-overflow
-Wstringop-overflow
-Wstringop-overflow=*type*

Warn for code that can be statically determined to cause buffer overflows or memory overruns, such as calls to `memcpy` and `strcpy` that overflow the destination buffer. The optional argument is one greater than the type of Object Size Checking to perform to determine the size of the destination. See Section 7.10 [Object Size Checking], page 861. The argument is meaningful only for string functions that operate on character arrays; raw memory functions like `memcpy` always use type-zero Object Size Checking.

The option also warns for calls that specify a size in excess of the largest possible object or at most `SIZE_MAX / 2` bytes.

The option produces the best results with optimization enabled but can detect a small subset of simple buffer overflows even without optimization in calls to the GCC built-in functions like `__builtin_memcpy` that correspond to the standard functions. In any case, the option warns about just a subset of buffer overflows detected by the corresponding overflow checking built-ins, such as `__builtin___memcpy_chk`, which can perform run-time checking if the access cannot be identified as safe at compile time.

For example, the option issues a warning for the `strcpy` call below because it copies at least 5 characters (the string `"blue"` including the terminating NUL) into the buffer of size 4.

```
enum Color { blue, purple, yellow };
const char* f (enum Color clr)
{
  static char buf [4];
  const char *str;
  switch (clr)
    {
      case blue: str = "blue"; break;
      case purple: str = "purple"; break;
      case yellow: str = "yellow"; break;
    }

  return strcpy (buf, str);   // warning here
}
```

The effect of this option is not limited to string or memory manipulation functions. In this example, a warning is diagnosed because a 1-element array is passed to a function requiring at least a 4-element array argument:

```
void f (int[static 4]);

void g (void)
{
  int *p = (int *) malloc (1 * sizeof(int));
  f (p);   // warning here
}
```

Option `-Wstringop-overflow=2` is enabled by default.

`-Wstringop-overflow`
`-Wstringop-overflow=1`

The `-Wstringop-overflow=1` option uses type-zero Object Size Checking to determine the sizes of destination objects. At this setting the option does not warn for writes past the end of subobjects of larger objects accessed by pointers unless the size of the largest surrounding object is known. When the destination may be one of several objects it is assumed to be the largest one of them. On Linux systems, when optimization is enabled at this setting the option warns for the same code as when the `_FORTIFY_SOURCE` macro is defined to a non-zero value.

`-Wstringop-overflow=2`

The `-Wstringop-overflow=2` option uses type-one Object Size Checking to determine the sizes of destination objects. At this setting the option warns about overflows when writing to members of the largest complete objects whose exact size is known. However, it does not warn for excessive writes to the same members of unknown objects referenced by pointers since they may point to arrays containing unknown numbers of elements. This is the default setting of the option.

`-Wstringop-overflow=3`

The `-Wstringop-overflow=3` option uses type-two Object Size Checking to determine the sizes of destination objects. At this setting the option warns about overflowing the smallest object or data member. This is the most restrictive setting of the option that may result in warnings for safe code.

`-Wstringop-overflow=4`

The `-Wstringop-overflow=4` option uses type-three Object Size Checking to determine the sizes of destination objects. At this setting the option warns about overflowing any data members, and when the destination is one of several objects it uses the size of the largest of them to decide whether to issue a warning. Similarly to `-Wstringop-overflow=3` this setting of the option may result in warnings for benign code.

`-Wno-stringop-overread`

Warn for calls to string manipulation functions such as `memchr`, or `strcpy` that are determined to read past the end of the source sequence.

Option `-Wstringop-overread` is enabled by default.

`-Wno-stringop-truncation`

Do not warn for calls to bounded string manipulation functions such as `strncat`, `strncpy`, and `stpncpy` that may either truncate the copied string or leave the destination unchanged.

In the following example, the call to `strncat` specifies a bound that is less than the length of the source string. As a result, the copy of the source will be truncated and so the call is diagnosed. To avoid the warning use `bufsize - strlen (buf) - 1` as the bound.

```
void append (char *buf, size_t bufsize)
{
  strncat (buf, ".txt", 3);
}
```

As another example, the following call to `strncpy` results in copying to `d` just the characters preceding the terminating NUL, without appending the NUL to the end. Assuming the result of `strncpy` is necessarily a NUL-terminated string is a common mistake, and so the call is diagnosed. To avoid the warning when the result is not expected to be NUL-terminated, call `memcpy` instead.

```
void copy (char *d, const char *s)
{
  strncpy (d, s, strlen (s));
}
```

In the following example, the call to `strncpy` specifies the size of the destination buffer as the bound. If the length of the source string is equal to or greater than this size the result of the copy will not be NUL-terminated. Therefore, the call is also diagnosed. To avoid the warning, specify `sizeof buf - 1` as the bound and set the last element of the buffer to `NUL`.

```
void copy (const char *s)
{
  char buf[80];
  strncpy (buf, s, sizeof buf);
  ...
}
```

In situations where a character array is intended to store a sequence of bytes with no terminating `NUL` such an array may be annotated with attribute `nonstring` to avoid this warning. Such arrays, however, are not suitable arguments to functions that expect `NUL`-terminated strings. To help detect accidental misuses of such arrays GCC issues warnings unless it can prove that the use is safe. See Section 6.4.2.1 [Common Variable Attributes], page 699.

`-Wstrict-flex-arrays` (C and C++ only)

Warn about improper usages of flexible array members according to the *level* of the `strict_flex_array (level)` attribute attached to the trailing array field of a structure if it's available, otherwise according to the *level* of the option `-fstrict-flex-arrays=level`. See Section 6.4.2.1 [Common Variable Attributes], page 699, for more information about the attribute, and Section 3.4 [C Dialect Options], page 45, for more information about the option. `-Wstrict-flex-arrays` is effective only when *level* is greater than 0.

When *level*=1, warnings are issued for a trailing array reference of a structure that have 2 or more elements if the trailing array is referenced as a flexible array member.

When *level*=2, in addition to *level*=1, additional warnings are issued for a trailing one-element array reference of a structure if the array is referenced as a flexible array member.

When *level*=3, in addition to *level*=2, additional warnings are issued for a trailing zero-length array reference of a structure if the array is referenced as a flexible array member.

This option is more effective when `-ftree-vrp` is active (the default for `-O2` and above) but some warnings may be diagnosed even without optimization.

`-Wsuggest-attribute=`*`attribute-name`*

Warn for cases where adding an attribute may be beneficial. The *attribute-names* currently supported are listed below.

`-Wsuggest-attribute=pure`
`-Wsuggest-attribute=const`
`-Wsuggest-attribute=noreturn`
`-Wmissing-noreturn`
`-Wsuggest-attribute=malloc`
`-Wsuggest-attribute=returns_nonnull`

Warn about functions that might be candidates for attributes `pure`, `const`, `noreturn`, `malloc` or `returns_nonnull`. The compiler only warns for functions visible in other compilation units or (in the case of `pure` and `const`) if it cannot prove that the function returns normally. A function returns normally if it doesn't contain an infinite loop or return abnormally by throwing, calling `abort` or trapping. This analysis requires option `-fipa-pure-const`, which is enabled by default at `-O` and higher. Higher optimization levels improve the accuracy of the analysis.

`-Wsuggest-attribute=format`
`-Wmissing-format-attribute`

Warn about function pointers that might be candidates for `format` attributes. Note these are only possible candidates, not absolute ones. GCC guesses that function pointers with `format` attributes that are used in assignment, initialization, parameter passing or return statements should have a corresponding `format` attribute in the resulting type. I.e. the left-hand side of the assignment or initialization, the type of the parameter variable, or the return type of the containing function respectively should also have a `format` attribute to avoid the warning.

GCC also warns about function definitions that might be candidates for `format` attributes. Again, these are only possible candidates. GCC guesses that `format` attributes might be appropriate for any function that calls a function like `vprintf` or `vscanf`, but this might not always be the case, and some functions for which `format` attributes are appropriate may not be detected.

`-Wsuggest-attribute=cold`

Warn about functions that might be candidates for `cold` attribute. This is based on static detection and generally only warns about functions which always leads to a call to another `cold` function such as wrappers of C++ `throw` or fatal error reporting functions leading to `abort`.

`-Walloc-size`
: Warn about calls to allocation functions decorated with attribute `alloc_size` that specify insufficient size for the target type of the pointer the result is assigned to, including those to the built-in forms of the functions `aligned_alloc`, `alloca`, `calloc`, `malloc`, and `realloc`.

`-Walloc-zero`
: Warn about calls to allocation functions decorated with attribute `alloc_size` that specify zero bytes, including those to the built-in forms of the functions `aligned_alloc`, `alloca`, `calloc`, `malloc`, and `realloc`. Because the behavior of these functions when called with a zero size differs among implementations (and in the case of `realloc` has been deprecated) relying on it may result in subtle portability bugs and should be avoided.

`-Wcalloc-transposed-args`
: Warn about calls to allocation functions decorated with attribute `alloc_size` with two arguments, which use `sizeof` operator as the earlier size argument and don't use it as the later size argument. This is a coding style warning. The first argument to `calloc` is documented to be number of elements in array, while the second argument is size of each element, so `calloc (n, sizeof (int))` is preferred over `calloc (sizeof (int), n)`. If `sizeof` in the earlier argument and not the latter is intentional, the warning can be suppressed by using `calloc (sizeof (struct S) + 0, n)` or `calloc (1 * sizeof (struct S), 4)` or using `sizeof` in the later argument as well.

`-Walloc-size-larger-than=byte-size`
: Warn about calls to functions decorated with attribute `alloc_size` that attempt to allocate objects larger than the specified number of bytes, or where the result of the size computation in an integer type with infinite precision would exceed the value of '`PTRDIFF_MAX`' on the target. `-Walloc-size-larger-than=`'`PTRDIFF_MAX`' is enabled by default. Warnings controlled by the option can be disabled either by specifying *byte-size* of '`SIZE_MAX`' or more or by `-Wno-alloc-size-larger-than`. See Section 6.4.1 [Function Attributes], page 621.

`-Wno-alloc-size-larger-than`
: Disable `-Walloc-size-larger-than=` warnings. The option is equivalent to `-Walloc-size-larger-than=`'`SIZE_MAX`' or larger.

`-Walloca`
: This option warns on all uses of `alloca` in the source.

`-Wauto-profile`
: Output warnings about auto-profile inconsistencies.

`-Wcannot-profile`
: Warn when profiling instrumentation was requested, but could not be applied to a certain function.

`-Walloca-larger-than=byte-size`
: This option warns on calls to `alloca` with an integer argument whose value is either zero, or that is not bounded by a controlling predicate that limits its

value to at most *byte-size*. It also warns for calls to `alloca` where the bound value is unknown. Arguments of non-integer types are considered unbounded even if they appear to be constrained to the expected range.

For example, a bounded case of `alloca` could be:

```
void func (size_t n)
{
  void *p;
  if (n <= 1000)
    p = alloca (n);
  else
    p = malloc (n);
  f (p);
}
```

In the above example, passing `-Walloca-larger-than=1000` would not issue a warning because the call to `alloca` is known to be at most 1000 bytes. However, if `-Walloca-larger-than=500` were passed, the compiler would emit a warning.

Unbounded uses, on the other hand, are uses of `alloca` with no controlling predicate constraining its integer argument. For example:

```
void func ()
{
  void *p = alloca (n);
  f (p);
}
```

If `-Walloca-larger-than=500` were passed, the above would trigger a warning, but this time because of the lack of bounds checking.

Note, that even seemingly correct code involving signed integers could cause a warning:

```
void func (signed int n)
{
  if (n < 500)
    {
      p = alloca (n);
      f (p);
    }
}
```

In the above example, *n* could be negative, causing a larger than expected argument to be implicitly cast into the `alloca` call.

This option also warns when `alloca` is used in a loop.

`-Walloca-larger-than=`'`PTRDIFF_MAX`' is enabled by default but is usually only effective when `-ftree-vrp` is active (default for `-O2` and above).

See also `-Wvla-larger-than=`'`byte-size`'.

`-Wno-alloca-larger-than`

Disable `-Walloca-larger-than=` warnings. The option is equivalent to `-Walloca-larger-than=`'`SIZE_MAX`' or larger.

`-Warith-conversion`

Do warn about implicit conversions from arithmetic operations even when conversion of the operands to the same type cannot change their values. This affects warnings from `-Wconversion`, `-Wfloat-conversion`, and `-Wsign-conversion`.

```
void f (char c, int i)
{
  c = c + i; // warns with -Wconversion
  c = c + 1; // only warns with -Warith-conversion
}
```

`-Warray-bounds`
`-Warray-bounds=n`

Warn about out of bounds subscripts or offsets into arrays. This warning is enabled by `-Wall`. It is more effective when `-ftree-vrp` is active (the default for `-O2` and above) but a subset of instances are issued even without optimization.

By default, the trailing array of a structure will be treated as a flexible array member by `-Warray-bounds` or `-Warray-bounds=n` if it is declared as either a flexible array member per C99 standard onwards ('`[]`'), a GCC zero-length array extension ('`[0]`'), or an one-element array ('`[1]`'). As a result, out of bounds subscripts or offsets into zero-length arrays or one-element arrays are not warned by default.

You can add the option `-fstrict-flex-arrays` or `-fstrict-flex-arrays=level` to control how this option treat trailing array of a structure as a flexible array member:

when *level*<=1, no change to the default behavior.

when *level*=2, additional warnings will be issued for out of bounds subscripts or offsets into one-element arrays;

when *level*=3, in addition to *level*=2, additional warnings will be issued for out of bounds subscripts or offsets into zero-length arrays.

`-Warray-bounds=1`

This is the default warning level of `-Warray-bounds` and is enabled by `-Wall`; higher levels are not, and must be explicitly requested.

`-Warray-bounds=2`

This warning level also warns about the intermediate results of pointer arithmetic that may yield out of bounds values. This warning level may give a larger number of false positives and is deactivated by default.

`-Wunterminated-string-initialization` (C and Objective-C only)

Warn about character arrays initialized as unterminated character sequences with a string literal, unless the declaration being initialized has the `nonstring` attribute. For example:

```
char arr[3] = "foo"; /* Warning.  */
char arr2[3] __attribute__((nonstring)) = "bar"; /* No warning.  */
```

This warning is enabled by `-Wextra`. If `-Wc++-compat` is enabled, the warning has slightly different wording and warns even if the declaration being initialized has the `nonstring` warning, as in C++ such initializations are an error.

`-Warray-compare`

Warn about equality and relational comparisons between two operands of array type. This comparison was deprecated in C++20. For example:

```
int arr1[5];
```

```
int arr2[5];
bool same = arr1 == arr2;
```

`-Warray-compare` is enabled by `-Wall`.

`-Warray-parameter`
`-Warray-parameter=`*n*

Warn about redeclarations of functions involving parameters of array or pointer types of inconsistent kinds or forms, and enable the detection of out-of-bounds accesses to such parameters by warnings such as `-Warray-bounds`.

If the first function declaration uses the array form for a parameter declaration, the bound specified in the array is assumed to be the minimum number of elements expected to be provided in calls to the function and the maximum number of elements accessed by it. Failing to provide arguments of sufficient size or accessing more than the maximum number of elements may be diagnosed by warnings such as `-Warray-bounds` or `-Wstringop-overflow`. At level 1, the warning diagnoses inconsistencies involving array parameters declared using the `T[static N]` form.

For example, the warning triggers for the second declaration of `f` because the first one with the keyword `static` specifies that the array argument must have at least four elements, while the second allows an array of any size to be passed to `f`.

```
void f (int[static 4]);
void f (int[]);           // warning (inconsistent array form)

void g (void)
{
  int *p = (int *)malloc (1 * sizeof (int));
  f (p);                  // warning (array too small)
  ...
}
```

At level 2 the warning also triggers for redeclarations involving any other inconsistency in array or pointer argument forms denoting array sizes. Pointers and arrays of unspecified bound are considered equivalent and do not trigger a warning.

```
void g (int*);
void g (int[]);     // no warning
void g (int[8]);    // warning (inconsistent array bound)
```

`-Warray-parameter=2` is included in `-Wall`. The `-Wvla-parameter` option triggers warnings for similar inconsistencies involving Variable Length Array arguments.

The short form of the option `-Warray-parameter` is equivalent to `-Warray-parameter=2`. The negative form `-Wno-array-parameter` is equivalent to `-Warray-parameter=0`.

`-Wattribute-alias=`*n*
`-Wno-attribute-alias`

Warn about declarations using the `alias` and similar attributes whose target is incompatible with the type of the alias. See Section 6.4.1 [Declaring Attributes of Functions], page 621.

-Wattribute-alias=1
: The default warning level of the -Wattribute-alias option diagnoses incompatibilities between the type of the alias declaration and that of its target. Such incompatibilities are typically indicative of bugs.

-Wattribute-alias=2
: At this level -Wattribute-alias also diagnoses cases where the attributes of the alias declaration are more restrictive than the attributes applied to its target. These mismatches can potentially result in incorrect code generation. In other cases they may be benign and could be resolved simply by adding the missing attribute to the target. For comparison, see the -Wmissing-attributes option, which controls diagnostics when the alias declaration is less restrictive than the target, rather than more restrictive.

  Attributes considered include alloc_align, alloc_size, cold, const, hot, leaf, malloc, nonnull, noreturn, nothrow, pure, returns_nonnull, and returns_twice.

-Wattribute-alias is equivalent to -Wattribute-alias=1. This is the default. You can disable these warnings with either -Wno-attribute-alias or -Wattribute-alias=0.

-Wbidi-chars=[none|unpaired|any|ucn]
: Warn about possibly misleading UTF-8 bidirectional control characters in comments, string literals, character constants, and identifiers. Such characters can change left-to-right writing direction into right-to-left (and vice versa), which can cause confusion between the logical order and visual order. This may be dangerous; for instance, it may seem that a piece of code is not commented out, whereas it in fact is.

  There are three levels of warning supported by GCC. The default is -Wbidi-chars=unpaired, which warns about improperly terminated bidi contexts. -Wbidi-chars=none turns the warning off. -Wbidi-chars=any warns about any use of bidirectional control characters.

  By default, this warning does not warn about UCNs. It is, however, possible to turn on such checking by using -Wbidi-chars=unpaired,ucn or -Wbidi-chars=any,ucn. Using -Wbidi-chars=ucn is valid, and is equivalent to -Wbidi-chars=unpaired,ucn, if no previous -Wbidi-chars=any was specified.

-Wbool-compare
: Warn about boolean expression compared with an integer value different from true/false. For instance, the following comparison is always false:

```
int n = 5;
...
if ((n > 1) == 2) { ... }
```

  This warning is enabled by -Wall.

`-Wbool-operation`

Warn about suspicious operations on expressions of a boolean type. For instance, bitwise negation of a boolean is very likely a bug in the program. For C, this warning also warns about incrementing or decrementing a boolean, which rarely makes sense. (In C++, decrementing a boolean is always invalid. Incrementing a boolean is invalid in C++17, and deprecated otherwise.)

This warning is enabled by `-Wall`.

`-Wduplicated-branches`

Warn when an if-else has identical branches. This warning detects cases like

```
if (p != NULL)
  return 0;
else
  return 0;
```

It doesn't warn when both branches contain just a null statement. This warning also warn for conditional operators:

```
  int i = x ? *p : *p;
```

`-Wduplicated-cond`

Warn about duplicated conditions in an if-else-if chain. For instance, warn for the following code:

```
if (p->q != NULL) { ... }
else if (p->q != NULL) { ... }
```

`-Wframe-address`

Warn when the '`__builtin_frame_address`' or '`__builtin_return_address`' is called with an argument greater than 0. Such calls may return indeterminate values or crash the program. The warning is included in `-Wall`.

`-Wno-discarded-qualifiers` (C and Objective-C only)

Do not warn if type qualifiers on pointers are being discarded. Typically, the compiler warns if a `const char *` variable is passed to a function that takes a `char *` parameter. This option can be used to suppress such a warning.

`-Wno-discarded-array-qualifiers` (C and Objective-C only)

Do not warn if type qualifiers on arrays which are pointer targets are being discarded. Typically, the compiler warns if a `const int (*)[]` variable is passed to a function that takes a `int (*)[]` parameter. This option can be used to suppress such a warning.

`-Wno-incompatible-pointer-types` (C and Objective-C only)

Do not warn when there is a conversion between pointers that have incompatible types. This warning is for cases not covered by `-Wno-pointer-sign`, which warns for pointer argument passing or assignment with different signedness.

By default, in C99 and later dialects of C, GCC treats this issue as an error. The error can be downgraded to a warning using `-fpermissive` (along with certain other errors), or for this error alone, with `-Wno-error=incompatible-pointer-types`.

This warning is upgraded to an error by `-pedantic-errors`.

`-Wno-int-conversion` (C and Objective-C only)

Do not warn about incompatible integer to pointer and pointer to integer conversions. This warning is about implicit conversions; for explicit conversions the warnings `-Wno-int-to-pointer-cast` and `-Wno-pointer-to-int-cast` may be used.

By default, in C99 and later dialects of C, GCC treats this issue as an error. The error can be downgraded to a warning using `-fpermissive` (along with certain other errors), or for this error alone, with `-Wno-error=int-conversion`.

This warning is upgraded to an error by `-pedantic-errors`.

`-Wzero-as-null-pointer-constant`

Warn when a literal '0' is used as null pointer constant.

`-Wzero-length-bounds`

Warn about accesses to elements of zero-length array members that might overlap other members of the same object. Declaring interior zero-length arrays is discouraged because accesses to them are undefined. See Section 6.2.2 [Zero Length], page 610.

For example, the first two stores in function `bad` are diagnosed because the array elements overlap the subsequent members `b` and `c`. The third store is diagnosed by `-Warray-bounds` because it is beyond the bounds of the enclosing object.

```
struct X { int a[0]; int b, c; };
struct X x;

void bad (void)
{
  x.a[0] = 0;   // -Wzero-length-bounds
  x.a[1] = 1;   // -Wzero-length-bounds
  x.a[2] = 2;   // -Warray-bounds
}
```

Option `-Wzero-length-bounds` is enabled by `-Warray-bounds`.

`-Wno-div-by-zero`

Do not warn about compile-time integer division by zero. Floating-point division by zero is not warned about, as it can be a legitimate way of obtaining infinities and NaNs.

`-Wsystem-headers`

Print warning messages for constructs found in system header files. Warnings from system headers are normally suppressed, on the assumption that they usually do not indicate real problems and would only make the compiler output harder to read. Using this command-line option tells GCC to emit warnings from system headers as if they occurred in user code. However, note that using `-Wall` in conjunction with this option does *not* warn about unknown pragmas in system headers—for that, `-Wunknown-pragmas` must also be used.

`-Wtautological-compare`

Warn if a self-comparison always evaluates to true or false. This warning detects various mistakes such as:

```
int i = 1;
```

```
...
if (i > i) { ... }
```

This warning also warns about bitwise comparisons that always evaluate to true or false, for instance:

```
if ((a & 16) == 10) { ... }
```

will always be false.

This warning is enabled by `-Wall`.

`-Wtrailing-whitespace`
`-Wtrailing-whitespace=`*kind*

Warn about trailing whitespace at the end of lines, including inside of comments, but excluding trailing whitespace in raw string literals. `-Wtrailing-whitespace` is equivalent to `-Wtrailing-whitespace=blanks` and warns just about trailing space and horizontal tab characters. `-Wtrailing-whitespace=any` warns about those or trailing form feed or vertical tab characters. `-Wno-trailing-whitespace` or `-Wtrailing-whitespace=none` disables the warning, which is the default. This is a coding style warning.

`-Wleading-whitespace=`*kind*

Warn about style issues in leading whitespace, but not about the amount of indentation. Some projects use coding styles where only spaces are used for indentation, others use only tabs, others use zero or more tabs (for multiples of `-ftabstop=`*n*) followed by zero or fewer than *n* spaces. No warning is emitted on lines which contain solely whitespace (although `-Wtrailing-whitespace=` warning might be emitted), no warnings are emitted inside of raw string literals. Warnings are also emitted for leading whitespace inside of multi-line comments. `-Wleading-whitespace=spaces` warns about leading whitespace other than spaces for projects which want to indent just by spaces. `-Wleading-whitespace=tabs` warns about leading whitespace other than horizontal tabs for projects which want to indent just by horizontal tabs. `-Wleading-whitespace=blanks` warns about leading whitespace other than spaces and horizontal tabs, or about horizontal tab after a space in the leading whitespace, or about *n* or more consecutive spaces in leading whitespace (where *n* is argument of `-ftabstop=`*n*, 8 by default). `-Wleading-whitespace=none` disables the warning, which is the default. This is a coding style warning.

`-Wtrampolines`

Warn about trampolines generated for pointers to nested functions. A trampoline is a small piece of data or code that is created at run time on the stack when the address of a nested function is taken, and is used to call the nested function indirectly. For some targets, it is made up of data only and thus requires no special treatment. But, for most targets, it is made up of code and thus requires the stack to be made executable in order for the program to work properly.

`-Wfloat-equal`

Warn if floating-point values are used in equality comparisons.

The idea behind this is that sometimes it is convenient (for the programmer) to consider floating-point values as approximations to infinitely precise real numbers. If you are doing this, then you need to compute (by analyzing the code, or in some other way) the maximum or likely maximum error that the computation introduces, and allow for it when performing comparisons (and when producing output, but that's a different problem). In particular, instead of testing for equality, you should check to see whether the two values have ranges that overlap; and this is done with the relational operators, so equality comparisons are probably mistaken.

`-Wtraditional` (C and Objective-C only)

Warn about certain constructs that behave differently in traditional and ISO C. Also warn about ISO C constructs that have no traditional C equivalent, and/or problematic constructs that should be avoided.

- Macro parameters that appear within string literals in the macro body. In traditional C macro replacement takes place within string literals, but in ISO C it does not.
- In traditional C, some preprocessor directives did not exist. Traditional preprocessors only considered a line to be a directive if the '`#`' appeared in column 1 on the line. Therefore `-Wtraditional` warns about directives that traditional C understands but ignores because the '`#`' does not appear as the first character on the line. It also suggests you hide directives like `#pragma` not understood by traditional C by indenting them. Some traditional implementations do not recognize `#elif`, so this option suggests avoiding it altogether.
- A function-like macro that appears without arguments.
- The unary plus operator.
- The '`U`' integer constant suffix, or the '`F`' or '`L`' floating-point constant suffixes. (Traditional C does support the '`L`' suffix on integer constants.) Note, these suffixes appear in macros defined in the system headers of most modern systems, e.g. the '`_MIN`'/'`_MAX`' macros in `<limits.h>`. Use of these macros in user code might normally lead to spurious warnings, however GCC's integrated preprocessor has enough context to avoid warning in these cases.
- A function declared external in one block and then used after the end of the block.
- A `switch` statement has an operand of type `long`.
- A non-`static` function declaration follows a `static` one. This construct is not accepted by some traditional C compilers.
- The ISO type of an integer constant has a different width or signedness from its traditional type. This warning is only issued if the base of the constant is ten. I.e. hexadecimal or octal values, which typically represent bit patterns, are not warned about.
- Usage of ISO string concatenation is detected.
- Initialization of automatic aggregates.

- Identifier conflicts with labels. Traditional C lacks a separate namespace for labels.
- Initialization of unions. If the initializer is zero, the warning is omitted. This is done under the assumption that the zero initializer in user code appears conditioned on e.g. `__STDC__` to avoid missing initializer warnings and relies on default initialization to zero in the traditional C case.
- Conversions by prototypes between fixed/floating-point values and vice versa. The absence of these prototypes when compiling with traditional C causes serious problems. This is a subset of the possible conversion warnings; for the full set use `-Wtraditional-conversion`.
- Use of ISO C style function definitions. This warning intentionally is *not* issued for prototype declarations or variadic functions because these ISO C features appear in your code when using libiberty's traditional C compatibility macros, `PARAMS` and `VPARAMS`. This warning is also bypassed for nested functions because that feature is already a GCC extension and thus not relevant to traditional C compatibility.

`-Wtraditional-conversion` (C and Objective-C only)
: Warn if a prototype causes a type conversion that is different from what would happen to the same argument in the absence of a prototype. This includes conversions of fixed point to floating and vice versa, and conversions changing the width or signedness of a fixed-point argument except when the same as the default promotion.

`-Wdeclaration-after-statement` (C and Objective-C only)
: Warn when a declaration is found after a statement in a block. This construct, known from C++, was introduced with ISO C99 and is by default allowed in GCC. It is not supported by ISO C90. See Section 6.12.15 [Mixed Labels and Declarations], page 823.

  This warning is upgraded to an error by `-pedantic-errors`.

`-Wshadow`
: Warn whenever a local variable or type declaration shadows another variable, parameter, type, class member (in C++), or instance variable (in Objective-C) or whenever a built-in function is shadowed. Note that in C++, the compiler warns if a local variable shadows an explicit typedef, but not if it shadows a struct/class/enum. If this warning is enabled, it includes also all instances of local shadowing. This means that `-Wno-shadow=local` and `-Wno-shadow=compatible-local` are ignored when `-Wshadow` is used. Same as `-Wshadow=global`.

`-Wno-shadow-ivar` (Objective-C only)
: Do not warn whenever a local variable shadows an instance variable in an Objective-C method.

`-Wshadow=global`
: Warn for any shadowing. Same as `-Wshadow`.

`-Wshadow=local`
: Warn when a local variable shadows another local variable or parameter.

`-Wshadow=compatible-local`

Warn when a local variable shadows another local variable or parameter whose type is compatible with that of the shadowing variable. In C++, type compatibility here means the type of the shadowing variable can be converted to that of the shadowed variable. The creation of this flag (in addition to `-Wshadow=local`) is based on the idea that when a local variable shadows another one of incompatible type, it is most likely intentional, not a bug or typo, as shown in the following example:

```
for (SomeIterator i = SomeObj.begin(); i != SomeObj.end(); ++i)
{
  for (int i = 0; i < N; ++i)
  {
    ...
  }
  ...
}
```

Since the two variable `i` in the example above have incompatible types, enabling only `-Wshadow=compatible-local` does not emit a warning. Because their types are incompatible, if a programmer accidentally uses one in place of the other, type checking is expected to catch that and emit an error or warning. Use of this flag instead of `-Wshadow=local` can possibly reduce the number of warnings triggered by intentional shadowing. Note that this also means that shadowing `const char *i` by `char *i` does not emit a warning.

This warning is also enabled by `-Wshadow=local`.

`-Wlarger-than=`*`byte-size`*

Warn whenever an object is defined whose size exceeds *byte-size*. `-Wlarger-than=`'`PTRDIFF_MAX`' is enabled by default. Warnings controlled by the option can be disabled either by specifying *byte-size* of '`SIZE_MAX`' or more or by `-Wno-larger-than`.

Also warn for calls to bounded functions such as `memchr` or `strnlen` that specify a bound greater than the largest possible object, which is '`PTRDIFF_MAX`' bytes by default. These warnings can only be disabled by `-Wno-larger-than`.

`-Wno-larger-than`

Disable `-Wlarger-than=` warnings. The option is equivalent to `-Wlarger-than=`'`SIZE_MAX`' or larger.

`-Wframe-larger-than=`*`byte-size`*

Warn if the size of a function frame exceeds *byte-size*. The computation done to determine the stack frame size is approximate and not conservative. The actual requirements may be somewhat greater than *byte-size* even if you do not get a warning. In addition, any space allocated via `alloca`, variable-length arrays, or related constructs is not included by the compiler when determining whether or not to issue a warning. `-Wframe-larger-than=`'`PTRDIFF_MAX`' is enabled by default. Warnings controlled by the option can be disabled either by specifying *byte-size* of '`SIZE_MAX`' or more or by `-Wno-frame-larger-than`.

-Wno-frame-larger-than
: Disable -Wframe-larger-than= warnings. The option is equivalent to -Wframe-larger-than='SIZE_MAX' or larger.

-Wfree-nonheap-object
: Warn when attempting to deallocate an object that was either not allocated on the heap, or by using a pointer that was not returned from a prior call to the corresponding allocation function. For example, because the call to stpcpy returns a pointer to the terminating nul character and not to the beginning of the object, the call to free below is diagnosed.

```
void f (char *p)
{
  p = stpcpy (p, "abc");
  // ...
  free (p);   // warning
}
```

-Wfree-nonheap-object is included in -Wall.

-Wstack-usage=*byte-size*
: Warn if the stack usage of a function might exceed *byte-size*. The computation done to determine the stack usage is conservative. Any space allocated via alloca, variable-length arrays, or related constructs is included by the compiler when determining whether or not to issue a warning.

The message is in keeping with the output of -fstack-usage.

- If the stack usage is fully static but exceeds the specified amount, it's:

```
warning: stack usage is 1120 bytes
```

- If the stack usage is (partly) dynamic but bounded, it's:

```
warning: stack usage might be 1648 bytes
```

- If the stack usage is (partly) dynamic and not bounded, it's:

```
warning: stack usage might be unbounded
```

-Wstack-usage='PTRDIFF_MAX' is enabled by default. Warnings controlled by the option can be disabled either by specifying *byte-size* of 'SIZE_MAX' or more or by -Wno-stack-usage.

-Wno-stack-usage
: Disable -Wstack-usage= warnings. The option is equivalent to -Wstack-usage='SIZE_MAX' or larger.

-Wunsafe-loop-optimizations
: Warn if the loop cannot be optimized because the compiler cannot assume anything on the bounds of the loop indices. With -funsafe-loop-optimizations warn if the compiler makes such assumptions.

-Wno-pedantic-ms-format (MinGW targets only)
: When used in combination with -Wformat and -pedantic without GNU extensions, this option disables the warnings about non-ISO printf / scanf format width specifiers I32, I64, and I used on Windows targets, which depend on the MS runtime.

-Wpointer-arith
Warn about anything that depends on the "size of" a function type or of void. GNU C assigns these types a size of 1, for convenience in calculations with void * pointers and pointers to functions. In C++, warn also when an arithmetic operation involves NULL. This warning is also enabled by -Wpedantic.

This warning is upgraded to an error by -pedantic-errors.

-Wno-pointer-compare
Do not warn if a pointer is compared with a zero character constant. This usually means that the pointer was meant to be dereferenced. For example:

```
const char *p = foo ();
if (p == '\0')
  return 42;
```

Note that the code above is invalid in C++11.

This warning is enabled by default.

-Wno-tsan
Disable warnings about unsupported features in ThreadSanitizer.

ThreadSanitizer does not support std::atomic_thread_fence and can report false positives.

-Wtype-limits
Warn if a comparison is always true or always false due to the limited range of the data type, but do not warn for constant expressions. For example, warn if an unsigned variable is compared against zero with < or >=. This warning is also enabled by -Wextra.

-Wabsolute-value (C and Objective-C only)
Warn for calls to standard functions that compute the absolute value of an argument when a more appropriate standard function is available. For example, calling abs(3.14) triggers the warning because the appropriate function to call to compute the absolute value of a double argument is fabs. The option also triggers warnings when the argument in a call to such a function has an unsigned type. This warning can be suppressed with an explicit type cast and it is also enabled by -Wextra.

-Wcomment
-Wcomments
Warn whenever a comment-start sequence '/*' appears in a '/*' comment, or whenever a backslash-newline appears in a '//' comment. This warning is enabled by -Wall.

-Wtrigraphs
Warn if any trigraphs are encountered that might change the meaning of the program. Trigraphs within comments are not warned about, except those that would form escaped newlines.

This option is implied by -Wall. If -Wall is not given, this option is still enabled unless trigraphs are enabled. To get trigraph conversion without warnings, but get the other -Wall warnings, use '-trigraphs -Wall -Wno-trigraphs'.

`-Wundef` Warn if an undefined identifier is evaluated in an `#if` directive. Such identifiers are replaced with zero.

`-Wexpansion-to-defined`
Warn whenever '`defined`' is encountered in the expansion of a macro (including the case where the macro is expanded by an '`#if`' directive). Such usage is not portable. This warning is also enabled by `-Wpedantic` and `-Wextra`.

`-Wunused-macros`
Warn about macros defined in the main file that are unused. A macro is *used* if it is expanded or tested for existence at least once. The preprocessor also warns if the macro has not been used at the time it is redefined or undefined.

Built-in macros, macros defined on the command line, and macros defined in include files are not warned about.

Note: If a macro is actually used, but only used in skipped conditional blocks, then the preprocessor reports it as unused. To avoid the warning in such a case, you might improve the scope of the macro's definition by, for example, moving it into the first skipped block. Alternatively, you could provide a dummy use with something like:

```
#if defined the_macro_causing_the_warning
#endif
```

`-Wno-endif-labels`
Do not warn whenever an `#else` or an `#endif` are followed by text. This sometimes happens in older programs with code of the form

```
#if FOO
...
#else FOO
...
#endif FOO
```

The second and third `FOO` should be in comments. This warning is on by default.

`-Wbad-function-cast` (C and Objective-C only)
Warn when a function call is cast to a non-matching type. For example, warn if a call to a function returning an integer type is cast to a pointer type.

`-Wc90-c99-compat` (C and Objective-C only)
Warn about features not present in ISO C90, but present in ISO C99. For instance, warn about use of variable length arrays, `long long` type, `bool` type, compound literals, designated initializers, and so on. This option is independent of the standards mode. Warnings are disabled in the expression that follows `__extension__`.

`-Wc99-c11-compat` (C and Objective-C only)
Warn about features not present in ISO C99, but present in ISO C11. For instance, warn about use of anonymous structures and unions, `_Atomic` type qualifier, `_Thread_local` storage-class specifier, `_Alignas` specifier, `Alignof` operator, `_Generic` keyword, and so on. This option is independent of the standards mode. Warnings are disabled in the expression that follows `__extension__`.

-Wc11-c23-compat (C and Objective-C only)
-Wc11-c2x-compat (C and Objective-C only)

Warn about features not present in ISO C11, but present in ISO C23. For instance, warn about omitting the string in _Static_assert, use of '[[]]' syntax for attributes, use of decimal floating-point types, and so on. This option is independent of the standards mode. Warnings are disabled in the expression that follows __extension__. The name -Wc11-c2x-compat is deprecated.

When not compiling in C23 mode, these warnings are upgraded to errors by -pedantic-errors.

-Wc23-c2y-compat (C and Objective-C only)
-Wc23-c2y-compat (C and Objective-C only)

Warn about features not present in ISO C23, but present in ISO C2Y. For instance, warn about _Generic selecting with a type name instead of an expression. This option is independent of the standards mode. Warnings are disabled in the expression that follows __extension__.

When not compiling in C2Y mode, these warnings are upgraded to errors by -pedantic-errors.

-Wc++-compat (C and Objective-C only)

Warn about ISO C constructs that are outside of the common subset of ISO C and ISO C++, e.g. request for implicit conversion from void * to a pointer to non-void type.

-Wc++11-compat (C++ and Objective-C++ only)

Warn about C++ constructs whose meaning differs between ISO C++ 1998 and ISO C++ 2011, e.g., identifiers in ISO C++ 1998 that are keywords in ISO C++ 2011. This warning turns on -Wnarrowing and is enabled by -Wall.

-Wc++14-compat (C++ and Objective-C++ only)

Warn about C++ constructs whose meaning differs between ISO C++ 2011 and ISO C++ 2014. This warning is enabled by -Wall.

-Wc++17-compat (C++ and Objective-C++ only)

Warn about C++ constructs whose meaning differs between ISO C++ 2014 and ISO C++ 2017. This warning is enabled by -Wall.

-Wc++20-compat (C++ and Objective-C++ only)

Warn about C++ constructs whose meaning differs between ISO C++ 2017 and ISO C++ 2020. This warning is enabled by -Wall.

-Wc++26-compat (C++ and Objective-C++ only)

Warn about C++ constructs whose meaning differs between ISO C++ 2023 and upcoming ISO C++ 2026. This warning is enabled by -Wall.

-Wno-c++11-extensions (C++ and Objective-C++ only)

Do not warn about C++11 constructs in code being compiled using an older C++ standard. Even without this option, some C++11 constructs will only be diagnosed if -Wpedantic is used.

`-Wno-c++14-extensions` (C++ and Objective-C++ only)
Do not warn about C++14 constructs in code being compiled using an older C++ standard. Even without this option, some C++14 constructs will only be diagnosed if `-Wpedantic` is used.

`-Wno-c++17-extensions` (C++ and Objective-C++ only)
Do not warn about C++17 constructs in code being compiled using an older C++ standard. Even without this option, some C++17 constructs will only be diagnosed if `-Wpedantic` is used.

`-Wno-c++20-extensions` (C++ and Objective-C++ only)
Do not warn about C++20 constructs in code being compiled using an older C++ standard. Even without this option, some C++20 constructs will only be diagnosed if `-Wpedantic` is used.

`-Wno-c++23-extensions` (C++ and Objective-C++ only)
Do not warn about C++23 constructs in code being compiled using an older C++ standard. Even without this option, some C++23 constructs will only be diagnosed if `-Wpedantic` is used.

`-Wno-c++26-extensions` (C++ and Objective-C++ only)
Do not warn about C++26 constructs in code being compiled using an older C++ standard. Even without this option, some C++26 constructs will only be diagnosed if `-Wpedantic` is used.

`-Wcast-qual`
Warn whenever a pointer is cast so as to remove a type qualifier from the target type. For example, warn if a `const char *` is cast to an ordinary `char *`.

Also warn when making a cast that introduces a type qualifier in an unsafe way. For example, casting `char **` to `const char **` is unsafe, as in this example:

```
/* p is char ** value.  */
const char **q = (const char **) p;
/* Assignment of readonly string to const char * is OK.  */
*q = "string";
/* Now char** pointer points to read-only memory.  */
**p = 'b';
```

`-Wcast-align`
Warn whenever a pointer is cast such that the required alignment of the target is increased. For example, warn if a `char *` is cast to an `int *` on machines where integers can only be accessed at two- or four-byte boundaries.

`-Wcast-align=strict`
Warn whenever a pointer is cast such that the required alignment of the target is increased. For example, warn if a `char *` is cast to an `int *` regardless of the target machine.

`-Wcast-function-type`
Warn when a function pointer is cast to an incompatible function pointer. In a cast involving function types with a variable argument list only the types of initial arguments that are provided are considered. Any parameter of pointer-type matches any other pointer-type. Any benign differences in integral types

are ignored, like `int` vs. `long` on ILP32 targets. Likewise type qualifiers are ignored. The function type `void (*) (void)` is special and matches everything, which can be used to suppress this warning. In a cast involving pointer to member types this warning warns whenever the type cast is changing the pointer to member type. This warning is enabled by `-Wextra`.

`-Wcast-user-defined`

Warn when a cast to reference type does not involve a user-defined conversion that the programmer might expect to be called.

```
struct A { operator const int&(); } a;
auto r = (int&)a; // warning
```

This warning is enabled by default.

`-Wwrite-strings`

When compiling C, give string constants the type `const char[length]` so that copying the address of one into a non-`const char *` pointer produces a warning. These warnings help you find at compile time code that can try to write into a string constant, but only if you have been very careful about using `const` in declarations and prototypes. Otherwise, it is just a nuisance. This is why we did not make `-Wall` request these warnings.

When compiling C++, warn about the deprecated conversion from string literals to `char *`. This warning is enabled by default for C++ programs.

This warning is upgraded to an error by `-pedantic-errors` in C++11 mode or later.

`-Wclobbered`

Warn for variables that might be changed by `longjmp` or `vfork`. This warning is also enabled by `-Wextra`.

`-Wno-complain-wrong-lang`

By default, language front ends complain when a command-line option is valid, but not applicable to that front end. This may be disabled with `-Wno-complain-wrong-lang`, which is mostly useful when invoking a single compiler driver for multiple source files written in different languages, for example:

```
$ g++ -fno-rtti a.cc b.f90
```

The driver `g++` invokes the C++ front end to compile `a.cc` and the Fortran front end to compile `b.f90`. The latter front end diagnoses '`f951: Warning: command-line option '-fno-rtti' is valid for C++/D/ObjC++ but not for Fortran`', which may be disabled with `-Wno-complain-wrong-lang`.

`-Wcompare-distinct-pointer-types` (C and Objective-C only)

Warn if pointers of distinct types are compared without a cast. This warning is enabled by default.

`-Wconversion`

Warn for implicit conversions that may alter a value. This includes conversions between real and integer, like `abs (x)` when `x` is `double`; conversions between signed and unsigned, like `unsigned ui = -1`; and conversions to smaller types, like `sqrtf (M_PI)`. Do not warn for explicit casts like `abs ((int) x)` and `ui`

`= (unsigned) -1`, or if the value is not changed by the conversion like in `abs (2.0)`. Warnings about conversions between signed and unsigned integers can be disabled by using `-Wno-sign-conversion`.

For C++, also warn for confusing overload resolution for user-defined conversions; and conversions that never use a type conversion operator: conversions to `void`, the same type, a base class or a reference to them. Warnings about conversions between signed and unsigned integers are disabled by default in C++ unless `-Wsign-conversion` is explicitly enabled.

Warnings about conversion from arithmetic on a small type back to that type are only given with `-Warith-conversion`.

`-Wdangling-else`

Warn about constructions where there may be confusion to which `if` statement an `else` branch belongs. Here is an example of such a case:

```
{
  if (a)
    if (b)
      foo ();
  else
    bar ();
}
```

In C/C++, every `else` branch belongs to the innermost possible `if` statement, which in this example is `if (b)`. This is often not what the programmer expected, as illustrated in the above example by indentation the programmer chose. When there is the potential for this confusion, GCC issues a warning when this flag is specified. To eliminate the warning, add explicit braces around the innermost `if` statement so there is no way the `else` can belong to the enclosing `if`. The resulting code looks like this:

```
{
  if (a)
    {
      if (b)
        foo ();
      else
        bar ();
    }
}
```

This warning is enabled by `-Wparentheses`.

`-Wdangling-pointer`
`-Wdangling-pointer=`*n*

Warn about uses of pointers (or C++ references) to objects with automatic storage duration after their lifetime has ended. This includes local variables declared in nested blocks, compound literals and other unnamed temporary objects. In addition, warn about storing the address of such objects in escaped pointers. The warning is enabled at all optimization levels but may yield different results with optimization than without.

`-Wdangling-pointer=1`

At level 1, the warning diagnoses only unconditional uses of dangling pointers.

-Wdangling-pointer=2
: At level 2, in addition to unconditional uses the warning also diagnoses conditional uses of dangling pointers.

The short form -Wdangling-pointer is equivalent to -Wdangling-pointer=2, while -Wno-dangling-pointer and -Wdangling-pointer=0 have the same effect of disabling the warnings. -Wdangling-pointer=2 is included in -Wall.

This example triggers the warning at level 1; the address of the unnamed temporary is unconditionally referenced outside of its scope.

```
char f (char c1, char c2, char c3)
{
  char *p;
  {
    p = (char[]) { c1, c2, c3 };
  }
  // warning: using dangling pointer 'p' to an unnamed temporary
  return *p;
}
```

In the following function the store of the address of the local variable x in the escaped pointer *p triggers the warning at level 1.

```
void g (int **p)
{
  int x = 7;
  // warning: storing the address of local variable 'x' in '*p'
  *p = &x;
}
```

In this example, the array *a* is out of scope when the pointer *s* is used. Since the code that sets s is conditional, the warning triggers at level 2.

```
extern void frob (const char *);
void h (char *s)
{
  if (!s)
    {
      char a[12] = "tmpname";
      s = a;
    }
  // warning: dangling pointer 's' to 'a' may be used
  frob (s);
}
```

-Wdate-time
: Warn when macros __TIME__, __DATE__ or __TIMESTAMP__ are encountered as they might prevent bitwise-identical reproducible compilations.

-Wempty-body
: Warn if an empty body occurs in an if, else or do while statement. This warning is also enabled by -Wextra.

-Wno-endif-labels
: Do not warn about stray tokens after #else and #endif.

`-Wenum-compare`

Warn about a comparison between values of different enumerated types. In C++ enumerated type mismatches in conditional expressions are also diagnosed and the warning is enabled by default. In C this warning is enabled by `-Wall`.

`-Wenum-conversion`

Warn when a value of enumerated type is implicitly converted to a different enumerated type. This warning is enabled by `-Wextra` in C.

`-Wenum-int-mismatch` (C and Objective-C only)

Warn about mismatches between an enumerated type and an integer type in declarations. For example:

```
enum E { l = -1, z = 0, g = 1 };
int foo(void);
enum E foo(void);
```

In C, an enumerated type is compatible with `char`, a signed integer type, or an unsigned integer type. However, since the choice of the underlying type of an enumerated type is implementation-defined, such mismatches may cause portability issues. In C++, such mismatches are an error. In C, this warning is enabled by `-Wall` and `-Wc++-compat`.

`-Wjump-misses-init` (C, Objective-C only)

Warn if a `goto` statement or a `switch` statement jumps forward across the initialization of a variable, or jumps backward to a label after the variable has been initialized. This only warns about variables that are initialized when they are declared. This warning is only supported for C and Objective-C; in C++ this sort of branch is an error in any case.

`-Wjump-misses-init` is included in `-Wc++-compat`. It can be disabled with the `-Wno-jump-misses-init` option.

`-Wsign-compare`

Warn when a comparison between signed and unsigned values could produce an incorrect result when the signed value is converted to unsigned. In C++, this warning is also enabled by `-Wall`. In C, it is also enabled by `-Wextra`.

`-Wsign-conversion`

Warn for implicit conversions that may change the sign of an integer value, like assigning a signed integer expression to an unsigned integer variable. An explicit cast silences the warning. In C, this option is enabled also by `-Wconversion`.

`-Wflex-array-member-not-at-end` (C and C++ only)

Warn when a structure containing a C99 flexible array member as the last field is not at the end of another structure. This warning warns e.g. about

```
struct flex  { int length; char data[]; };
struct mid_flex { int m; struct flex flex_data; int n; };
```

`-Wfloat-conversion`

Warn for implicit conversions that reduce the precision of a real value. This includes conversions from real to integer, and from higher precision real to lower precision real values. This option is also enabled by `-Wconversion`.

`-Wno-scalar-storage-order`
: Do not warn on suspicious constructs involving reverse scalar storage order.

`-Wsizeof-array-div`
: Warn about divisions of two sizeof operators when the first one is applied to an array and the divisor does not equal the size of the array element. In such a case, the computation will not yield the number of elements in the array, which is likely what the user intended. This warning warns e.g. about

```
int fn ()
{
  int arr[10];
  return sizeof (arr) / sizeof (short);
}
```

This warning is enabled by `-Wall`.

`-Wsizeof-pointer-div`
: Warn for suspicious divisions of two sizeof expressions that divide the pointer size by the element size, which is the usual way to compute the array size but won't work out correctly with pointers. This warning warns e.g. about `sizeof (ptr) / sizeof (ptr[0])` if `ptr` is not an array, but a pointer. This warning is enabled by `-Wall`.

`-Wsizeof-pointer-memaccess`
: Warn for suspicious length parameters to certain string and memory built-in functions if the argument uses `sizeof`. This warning triggers for example for `memset (ptr, 0, sizeof (ptr));` if `ptr` is not an array, but a pointer, and suggests a possible fix, or about `memcpy (&foo, ptr, sizeof (&foo));`. `-Wsizeof-pointer-memaccess` also warns about calls to bounded string copy functions like `strncat` or `strncpy` that specify as the bound a `sizeof` expression of the source array. For example, in the following function the call to `strncat` specifies the size of the source string as the bound. That is almost certainly a mistake and so the call is diagnosed.

```
void make_file (const char *name)
{
  char path[PATH_MAX];
  strncpy (path, name, sizeof path - 1);
  strncat (path, ".text", sizeof ".text");
  ...
}
```

The `-Wsizeof-pointer-memaccess` option is enabled by `-Wall`.

`-Wno-sizeof-array-argument`
: Do not warn when the `sizeof` operator is applied to a parameter that is declared as an array in a function definition. This warning is enabled by default for C and C++ programs.

`-Wmemset-elt-size`
: Warn for suspicious calls to the `memset` built-in function, if the first argument references an array, and the third argument is a number equal to the number of elements, but not equal to the size of the array in memory. This indicates that the user has omitted a multiplication by the element size. This warning is enabled by `-Wall`.

`-Wmemset-transposed-args`

Warn for suspicious calls to the `memset` built-in function where the second argument is not zero and the third argument is zero. For example, the call `memset (buf, sizeof buf, 0)` is diagnosed because `memset (buf, 0, sizeof buf)` was meant instead. The diagnostic is only emitted if the third argument is a literal zero. Otherwise, if it is an expression that is folded to zero, or a cast of zero to some type, it is far less likely that the arguments have been mistakenly transposed and no warning is emitted. This warning is enabled by `-Wall`.

`-Waddress`

Warn about suspicious uses of address expressions. These include comparing the address of a function or a declared object to the null pointer constant such as in

```
void f (void);
void g (void)
{
  if (!f)   // warning: expression evaluates to false
    abort ();
}
```

comparisons of a pointer to a string literal, such as in

```
void f (const char *x)
{
  if (x == "abc")   // warning: expression evaluates to false
    puts ("equal");
}
```

and tests of the results of pointer addition or subtraction for equality to null, such as in

```
void f (const int *p, int i)
{
  return p + i == NULL;
}
```

Such uses typically indicate a programmer error: the address of most functions and objects necessarily evaluates to true (the exception are weak symbols), so their use in a conditional might indicate missing parentheses in a function call or a missing dereference in an array expression. The subset of the warning for object pointers can be suppressed by casting the pointer operand to an integer type such as `intptr_t` or `uintptr_t`. Comparisons against string literals result in unspecified behavior and are not portable, and suggest the intent was to call `strcmp`. The warning is suppressed if the suspicious expression is the result of macro expansion. `-Waddress` warning is enabled by `-Wall`.

`-Wno-address-of-packed-member`

Do not warn when the address of packed member of struct or union is taken, which usually results in an unaligned pointer value. This is enabled by default.

`-Wlogical-op`

Warn about suspicious uses of logical operators in expressions. This includes using logical operators in contexts where a bitwise operator is likely to be expected. Also warns when the operands of a logical operator are the same:

```
extern int a;
if (a < 0 && a < 0) { ... }
```

`-Wlogical-not-parentheses`
: Warn about logical not used on the left hand side operand of a comparison. This option does not warn if the right operand is considered to be a boolean expression. Its purpose is to detect suspicious code like the following:

```
int a;
...
if (!a > 1) { ... }
```

It is possible to suppress the warning by wrapping the LHS into parentheses:

```
if ((!a) > 1) { ... }
```

This warning is enabled by `-Wall`.

`-Waggregate-return`
: Warn if any functions that return structures or unions are defined or called. (In languages where you can return an array, this also elicits a warning.)

`-Wno-aggressive-loop-optimizations`
: Do not warn if the compiler detects undefined behavior in a loop with a constant number of iterations. `-Waggressive-loop-optimizations` is enabled by default.

`-Wno-attributes`
: Do not warn if an unexpected `__attribute__` is used, such as unrecognized attributes, function attributes applied to variables, etc. This does not stop errors for incorrect use of supported attributes.

Warnings about ill-formed uses of standard attributes are upgraded to errors by `-pedantic-errors`.

Additionally, using `-Wno-attributes=`, it is possible to suppress warnings about unknown scoped attributes (in C++11 and C23). For example, `-Wno-attributes=vendor::attr` disables warning about the following declaration:

```
[[vendor::attr]] void f();
```

It is also possible to disable warning about all attributes in a namespace using `-Wno-attributes=vendor::` which prevents warning about both of these declarations:

```
[[vendor::safe]] void f();
[[vendor::unsafe]] void f2();
```

Note that `-Wno-attributes=` does not imply `-Wno-attributes`.

`-Wno-builtin-declaration-mismatch`
: Warn if a built-in function is declared with an incompatible signature or as a non-function, or when a built-in function declared with a type that does not include a prototype is called with arguments whose promoted types do not match those expected by the function. When `-Wextra` is specified, also warn when a built-in function that takes arguments is declared without a prototype. The `-Wbuiltin-declaration-mismatch` warning is enabled by default. To avoid the warning include the appropriate header to bring the prototypes of built-in functions into scope.

For example, the call to `memset` below is diagnosed by the warning because the function expects a value of type `size_t` as its argument but the type of `32` is `int`. With `-Wextra`, the declaration of the function is diagnosed as well.

```
extern void* memset ();
void f (void *d)
{
  memset (d, '\0', 32);
}
```

`-Wno-builtin-macro-redefined`
: Do not warn if certain built-in macros are redefined. This suppresses warnings for redefinition of `__TIMESTAMP__`, `__TIME__`, `__DATE__`, `__FILE__`, and `__BASE_FILE__`.

`-Wkeyword-macro`
: Warn if a keyword is defined as a macro or undefined. For C++ identifiers with special meaning or standard attribute identifiers are diagnosed as well. This warning is enabled by default for C++26 if `-Wpedantic` and emits a pedwarn in that case.

`-Wfree-labels` (C and Objective-C only)
: Warn if a label is applied to a non-statement, or occurs at the end of a compound statement. Such labels are allowed by C23 and later dialects of C, and are available as a GCC extension in all other dialects.

  This warning is also enabled by `-Wc11-c23-compat`. It is turned into an error if building for a C version before C23 by `-pedantic-errors`.

`-Wheader-guard`
: Warn if a valid preprocessor header multiple inclusion guard has a `#define` directive right after `#ifndef` or `#if !defined` directive for the multiple inclusion guard, which defines a different macro from the guard macro with a similar name, the actual multiple inclusion guard macro isn't defined at the corresponding `#ifndef` directive at the end of the header, and the `#define` directive defines an object-like macro with empty definition. In such case, it often is just a misspelled guard name, either in the `#ifndef` or `#if !defined` directive or in the subsequent `#define` directive. This warning is enabled by `-Wall`.

`-Wstrict-prototypes` (C and Objective-C only)
: Warn if a function is declared or defined without specifying the argument types. (An old-style function definition is permitted without a warning if preceded by a declaration that specifies the argument types.)

`-Wold-style-declaration` (C and Objective-C only)
: Warn for obsolescent usages, according to the C Standard, in a declaration. For example, warn if storage-class specifiers like `static` are not the first things in a declaration. This warning is also enabled by `-Wextra`.

`-Wold-style-definition` (C and Objective-C only)
: Warn if an old-style function definition is used. A warning is given even if there is a previous prototype. A definition using '`()`' is not considered an old-style definition in C23 mode, because it is equivalent to '`(void)`' in that case, but is considered an old-style definition for older standards.

`-Wmultiple-parameter-fwd-decl-lists` (C and Objective-C only)
Warn if more than one list of forward declarations of parameters appears in a function prototype. This warning is also enabled by `-Wextra`.

`-Wdeprecated-non-prototype` (C and Objective-C only)
Warn if a function declared with an empty parameter list '`()`' is called with one or more arguments, or if a function definition with one or more parameters is encountered after such a declaration. Both cases are errors in C23 and later dialects of C.

This warning is also enabled by `-Wc11-c23-compat`.

`-Wmissing-parameter-name` (C and Objective-C only)
Warn if a function definition omits a parameter name, specifying only its type. This can be used to document that a parameter is unused in the definition. It is part of C23 and later dialects of C, and available as a GCC extension in all other dialects.

This warning is also enabled by `-Wc11-c23-compat`. It is turned into an error if building for a C version before C23 by `-pedantic-errors`.

`-Wmissing-parameter-type` (C and Objective-C only)
A function parameter is declared without a type specifier in K&R-style functions:

```
void foo(bar) { }
```

This warning is also enabled by `-Wextra`.

`-Wno-declaration-missing-parameter-type` (C and Objective-C only)
Do not warn if a function declaration contains a parameter name without a type. Such function declarations do not provide a function prototype and prevent most type checking in function calls.

This warning is enabled by default. In C99 and later dialects of C, it is treated as an error. The error can be downgraded to a warning using `-fpermissive` (along with certain other errors), or for this error alone, with `-Wno-error=declaration-missing-parameter-type`.

This warning is upgraded to an error by `-pedantic-errors`.

`-Wmissing-prototypes` (C and Objective-C only)
Warn if a global function is defined without a previous prototype declaration. This warning is issued even if the definition itself provides a prototype. Use this option to detect global functions that do not have a matching prototype declaration in a header file. This option is not valid for C++ because all function declarations provide prototypes and a non-matching declaration declares an overload rather than conflict with an earlier declaration. Use `-Wmissing-declarations` to detect missing declarations in C++.

`-Wmissing-variable-declarations` (C and Objective-C only)
Warn if a global variable is defined without a previous declaration. Use this option to detect global variables that do not have a matching extern declaration in a header file.

`-Wmissing-declarations`

Warn if a global function is defined without a previous declaration. Do so even if the definition itself provides a prototype. Use this option to detect global functions that are not declared in header files. In C, no warnings are issued for functions with previous non-prototype declarations; use `-Wmissing-prototypes` to detect missing prototypes. In C++, no warnings are issued for function templates, or for inline functions, or for functions in anonymous namespaces.

`-Wmissing-field-initializers`

Warn if a structure's initializer has some fields missing. For example, the following code causes such a warning, because `x.h` is implicitly zero:

```
struct s { int f, g, h; };
struct s x = { 3, 4 };
```

In C this option does not warn about designated initializers, so the following modification does not trigger a warning:

```
struct s { int f, g, h; };
struct s x = { .f = 3, .g = 4 };
```

In C this option does not warn about the universal zero initializer '`{ 0 }`':

```
struct s { int f, g, h; };
struct s x = { 0 };
```

Likewise, in C++ this option does not warn about the empty { } initializer, for example:

```
struct s { int f, g, h; };
s x = { };
```

This warning is included in `-Wextra`. To get other `-Wextra` warnings without this one, use `-Wextra -Wno-missing-field-initializers`.

`-Wno-missing-requires`

By default, the compiler warns about a concept-id appearing as a C++20 simple-requirement:

```
bool satisfied = requires { C<T> };
```

Here '`satisfied`' will be true if '`C<T>`' is a valid expression, which it is for all T. Presumably the user meant to write

```
bool satisfied = requires { requires C<T> };
```

so '`satisfied`' is only true if concept '`C`' is satisfied for type '`T`'.

This warning can be disabled with `-Wno-missing-requires`.

`-Wno-missing-template-keyword`

The member access tokens ., `->` and :: must be followed by the `template` keyword if the parent object is dependent and the member being named is a template.

```
template <class X>
void DoStuff (X x)
{
  x.template DoSomeOtherStuff<X>(); // Good.
  x.DoMoreStuff<X>(); // Warning, x is dependent.
}
```

In rare cases it is possible to get false positives. To silence this, wrap the expression in parentheses. For example, the following is treated as a template, even where m and N are integers:

```
void NotATemplate (my_class t)
{
  int N = 5;

  bool test = t.m < N > (0); // Treated as a template.
  test = (t.m < N) > (0); // Same meaning, but not treated as a template.
}
```

This warning can be disabled with `-Wno-missing-template-keyword`.

`-Wno-multichar`

Do not warn if a multicharacter constant (‘`'FOOF'`’) is used. Usually they indicate a typo in the user's code, as they have implementation-defined values, and should not be used in portable code.

`-Wnormalized=`[`none`|`id`|`nfc`|`nfkc`]

In ISO C and ISO C++, two identifiers are different if they are different sequences of characters. However, sometimes when characters outside the basic ASCII character set are used, you can have two different character sequences that look the same. To avoid confusion, the ISO 10646 standard sets out some *normalization rules* which when applied ensure that two sequences that look the same are turned into the same sequence. GCC can warn you if you are using identifiers that have not been normalized; this option controls that warning.

There are four levels of warning supported by GCC. The default is `-Wnormalized=nfc`, which warns about any identifier that is not in the ISO 10646 “C” normalized form, *NFC*. NFC is the recommended form for most uses. It is equivalent to `-Wnormalized`.

Unfortunately, there are some characters allowed in identifiers by ISO C and ISO C++ that, when turned into NFC, are not allowed in identifiers. That is, there's no way to use these symbols in portable ISO C or C++ and have all your identifiers in NFC. `-Wnormalized=id` suppresses the warning for these characters. It is hoped that future versions of the standards involved will correct this, which is why this option is not the default.

You can switch the warning off for all characters by writing `-Wnormalized=none` or `-Wno-normalized`. You should only do this if you are using some other normalization scheme (like “D”), because otherwise you can easily create bugs that are literally impossible to see.

Some characters in ISO 10646 have distinct meanings but look identical in some fonts or display methodologies, especially once formatting has been applied. For instance `\u207F`, “SUPERSCRIPT LATIN SMALL LETTER N”, displays just like a regular `n` that has been placed in a superscript. ISO 10646 defines the *NFKC* normalization scheme to convert all these into a standard form as well, and GCC warns if your code is not in NFKC if you use `-Wnormalized=nfkc`. This warning is comparable to warning about every identifier that contains the letter O because it might be confused with the digit 0, and so is not the default, but may be useful as a local coding convention if the programming environment cannot be fixed to display these characters distinctly.

`-Wno-attribute-warning`
: Do not warn about usage of functions (see Section 6.4.1 [Function Attributes], page 621) declared with `warning` attribute. By default, this warning is enabled. `-Wno-attribute-warning` can be used to disable the warning or `-Wno-error=attribute-warning` can be used to disable the error when compiled with `-Werror` flag.

`-Wno-deprecated`
: Do not warn about usage of deprecated features. See Section 8.10 [Deprecated Features], page 1074.

  In C++, explicitly specifying `-Wdeprecated` also enables warnings about some features that are deprecated in later language standards, specifically `-Wcomma-subscript`, `-Wvolatile`, `-Wdeprecated-enum-float-conversion`, `-Wdeprecated-enum-enum-conversion`, `-Wdeprecated-literal-operator`, and `-Wdeprecated-variadic-comma-omission`.

`-Wno-deprecated-declarations`
: Do not warn about uses of functions (see Section 6.4.1 [Function Attributes], page 621), variables (see Section 6.4.2 [Variable Attributes], page 699), and types (see Section 6.4.3 [Type Attributes], page 715) marked as deprecated by using the `deprecated` attribute.

`-Wno-overflow`
: Do not warn about compile-time overflow in constant expressions.

`-Wno-odr`
: Warn about One Definition Rule violations during link-time optimization. Enabled by default.

`-Wopenacc-parallelism`
: Warn about potentially suboptimal choices related to OpenACC parallelism.

`-Wno-openmp`
: Warn about suspicious OpenMP code.

`-Wopenmp-simd`
: Warn if the vectorizer cost model overrides the OpenMP simd directive set by user. The `-fsimd-cost-model=unlimited` option can be used to relax the cost model.

`-Woverride-init` (C and Objective-C only)
: Warn if an initialized field without side effects is overridden when using designated initializers (see Section 6.2.11 [Designated Initializers], page 616).

  This warning is included in `-Wextra`. To get other `-Wextra` warnings without this one, use `-Wextra -Wno-override-init`.

`-Wno-override-init-side-effects` (C and Objective-C only)
: Do not warn if an initialized field with side effects is overridden when using designated initializers (see Section 6.2.11 [Designated Initializers], page 616). This warning is enabled by default.

`-Wpacked` Warn if a structure is given the packed attribute, but the packed attribute has no effect on the layout or size of the structure. Such structures may be mis-aligned for little benefit. For instance, in this code, the variable `f.x` in `struct bar` is misaligned even though `struct bar` does not itself have the packed attribute:

```
struct foo {
  int x;
  char a, b, c, d;
} __attribute__((packed));
struct bar {
  char z;
  struct foo f;
};
```

`-Wnopacked-bitfield-compat`

The 4.1, 4.2 and 4.3 series of GCC ignore the `packed` attribute on bit-fields of type `char`. This was fixed in GCC 4.4 but the change can lead to differences in the structure layout. GCC informs you when the offset of such a field has changed in GCC 4.4. For example there is no longer a 4-bit padding between field `a` and `b` in this structure:

```
struct foo
{
  char a:4;
  char b:8;
} __attribute__ ((packed));
```

This warning is enabled by default. Use `-Wno-packed-bitfield-compat` to disable this warning.

`-Wpacked-not-aligned` (C, C++, Objective-C and Objective-C++ only)

Warn if a structure field with explicitly specified alignment in a packed struct or union is misaligned. For example, a warning will be issued on `struct S`, like, `warning: alignment 1 of 'struct S' is less than 8`, in this code:

```
struct __attribute__ ((aligned (8))) S8 { char a[8]; };
struct __attribute__ ((packed)) S {
  struct S8 s8;
};
```

This warning is enabled by `-Wall`.

`-Wpadded` Warn if padding is included in a structure, either to align an element of the structure or to align the whole structure. Sometimes when this happens it is possible to rearrange the fields of the structure to reduce the padding and so make the structure smaller.

`-Wredundant-decls`

Warn if anything is declared more than once in the same scope, even in cases where multiple declaration is valid and changes nothing.

`-Wrestrict`

Warn when an object referenced by a `restrict`-qualified parameter (or, in C++, a `__restrict`-qualified parameter) is aliased by another argument, or when copies between such objects overlap. For example, the call to the `strcpy` function below attempts to truncate the string by replacing its initial characters with the last four. However, because the call writes the terminating NUL into a[4], the copies overlap and the call is diagnosed.

```
void foo (void)
{
  char a[] = "abcd1234";
  strcpy (a, a + 4);
  ...
}
```

The -Wrestrict option detects some instances of simple overlap even without optimization but works best at -O2 and above. It is included in -Wall.

-Wnested-externs (C and Objective-C only)
Warn if an extern declaration is encountered within a function.

-Winline Warn if a function that is declared as inline cannot be inlined. Even with this option, the compiler does not warn about failures to inline functions declared in system headers.

The compiler uses a variety of heuristics to determine whether or not to inline a function. For example, the compiler takes into account the size of the function being inlined and the amount of inlining that has already been done in the current function. Therefore, seemingly insignificant changes in the source program can cause the warnings produced by -Winline to appear or disappear.

-Winterference-size
Warn about use of C++17 std::hardware_destructive_interference_size without specifying its value with --param destructive-interference-size. Also warn about questionable values for that option.

This variable is intended to be used for controlling class layout, to avoid false sharing in concurrent code:

```
struct independent_fields {
  alignas(std::hardware_destructive_interference_size)
    std::atomic<int> one;
  alignas(std::hardware_destructive_interference_size)
    std::atomic<int> two;
};
```

Here 'one' and 'two' are intended to be far enough apart that stores to one won't require accesses to the other to reload the cache line.

By default, --param destructive-interference-size and --param constructive-interference-size are set based on the current -mtune option, typically to the L1 cache line size for the particular target CPU, sometimes to a range if tuning for a generic target. So all translation units that depend on ABI compatibility for the use of these variables must be compiled with the same -mtune (or -mcpu).

If ABI stability is important, such as if the use is in a header for a library, you should probably not use the hardware interference size variables at all. Alternatively, you can force a particular value with --param.

If you are confident that your use of the variable does not affect ABI outside a single build of your project, you can turn off the warning with -Wno-interference-size.

`-Wint-in-bool-context`
: Warn for suspicious use of integer values where boolean values are expected, such as conditional expressions (?:) using non-boolean integer constants in boolean context, like `if (a <= b ? 2 : 3)`. Or left shifting of signed integers in boolean context, like `for (a = 0; 1 << a; a++);`. Likewise for all kinds of multiplications regardless of the data type. This warning is enabled by `-Wall`.

`-Wno-int-to-pointer-cast`
: Suppress warnings from casts to pointer type of an integer of a different size. In C++, casting to a pointer type of smaller size is an error. `Wint-to-pointer-cast` is enabled by default.

`-Wno-pointer-to-int-cast` (C and Objective-C only)
: Suppress warnings from casts from a pointer to an integer type of a different size.

`-Winvalid-pch`
: Warn if a precompiled header (see Section 3.23 [Precompiled Headers], page 582) is found in the search path but cannot be used.

`-Winvalid-utf8`
: Warn if an invalid UTF-8 character is found. This warning is on by default for C++23 if `-finput-charset=UTF-8` is used and turned into error with `-pedantic-errors`.

`-Wno-unicode`
: Don't diagnose invalid forms of delimited or named escape sequences which are treated as separate tokens. `Wunicode` is enabled by default.

`-Wlong-long`
: Warn if `long long` type is used. This is enabled by either `-Wpedantic` or `-Wtraditional` in ISO C90 and C++98 modes. To inhibit the warning messages, use `-Wno-long-long`.

  This warning is upgraded to an error by `-pedantic-errors`.

`-Wvariadic-macros`
: Warn if variadic macros are used in ISO C90 mode, or if the GNU alternate syntax is used in ISO C99 mode. This is enabled by either `-Wpedantic` or `-Wtraditional`. To inhibit the warning messages, use `-Wno-variadic-macros`.

`-Wno-varargs`
: Do not warn upon questionable usage of the macros used to handle variable arguments like `va_start`. These warnings are enabled by default.

`-Wvector-operation-performance`
: Warn if vector operation is not implemented via SIMD capabilities of the architecture. Mainly useful for the performance tuning. Vector operation can be implemented `piecewise`, which means that the scalar operation is performed on every vector element; `in parallel`, which means that the vector operation is implemented using scalars of wider type, which normally is more performance efficient; and `as a single scalar`, which means that vector fits into a scalar type.

`-Wvla` Warn if a variable-length array is used in the code. `-Wno-vla` prevents the `-Wpedantic` warning of the variable-length array.

This warning is upgraded to an error by `-pedantic-errors`.

`-Wvla-larger-than=`*byte-size*

If this option is used, the compiler warns for declarations of variable-length arrays whose size is either unbounded, or bounded by an argument that allows the array size to exceed *byte-size* bytes. This is similar to how `-Walloca-larger-than=`*byte-size* works, but with variable-length arrays.

Note that GCC may optimize small variable-length arrays of a known value into plain arrays, so this warning may not get triggered for such arrays.

`-Wvla-larger-than=`'`PTRDIFF_MAX`' is enabled by default but is typically only effective when `-ftree-vrp` is active (default for `-O2` and above).

See also `-Walloca-larger-than=`*byte-size*.

`-Wno-vla-larger-than`

Disable `-Wvla-larger-than=` warnings. The option is equivalent to `-Wvla-larger-than=`'`SIZE_MAX`' or larger.

`-Wvla-parameter`

Warn about redeclarations of functions involving arguments of Variable Length Array types of inconsistent kinds or forms, and enable the detection of out-of-bounds accesses to such parameters by warnings such as `-Warray-bounds`.

If the first function declaration uses the VLA form the bound specified in the array is assumed to be the minimum number of elements expected to be provided in calls to the function and the maximum number of elements accessed by it. Failing to provide arguments of sufficient size or accessing more than the maximum number of elements may be diagnosed.

For example, the warning triggers for the following redeclarations because the first one allows an array of any size to be passed to `f` while the second one specifies that the array argument must have at least `n` elements. In addition, calling `f` with the associated VLA bound parameter in excess of the actual VLA bound triggers a warning as well.

```
void f (int n, int[n]);
// warning: argument 2 previously declared as a VLA
void f (int, int[]);

void g (int n)
{
    if (n > 4)
      return;
    int a[n];
    // warning: access to a by f may be out of bounds
    f (sizeof a, a);
  ...
}
```

`-Wvla-parameter` is included in `-Wall`. The `-Warray-parameter` option triggers warnings for similar problems involving ordinary array arguments.

`-Wvolatile-register-var`
: Warn if a register variable is declared volatile. The volatile modifier does not inhibit all optimizations that may eliminate reads and/or writes to register variables. This warning is enabled by `-Wall`.

`-Wno-xor-used-as-pow` (C, C++, Objective-C and Objective-C++ only)
: Disable warnings about uses of `^`, the exclusive or operator, where it appears the code meant exponentiation. Specifically, the warning occurs when the left-hand side is the decimal constant 2 or 10 and the right-hand side is also a decimal constant.

  In C and C++, `^` means exclusive or, whereas in some other languages (e.g. TeX and some versions of BASIC) it means exponentiation.

  This warning can be silenced by converting one of the operands to hexadecimal as well as by compiling with `-Wno-xor-used-as-pow`.

`-Wdisabled-optimization`
: Warn if a requested optimization pass is disabled. This warning does not generally indicate that there is anything wrong with your code; it merely indicates that GCC's optimizers are unable to handle the code effectively. Often, the problem is that your code is too big or too complex; GCC refuses to optimize programs when the optimization itself is likely to take inordinate amounts of time.

`-Wpointer-sign` (C and Objective-C only)
: Warn for pointer argument passing or assignment with different signedness. This option is only supported for C and Objective-C. It is implied by `-Wall` and by `-Wpedantic`, which can be disabled with `-Wno-pointer-sign`.

  This warning is upgraded to an error by `-pedantic-errors`.

`-Wstack-protector`
: This option is only active when `-fstack-protector` is active. It warns about functions that are not protected against stack smashing.

`-Woverlength-strings`
: Warn about string constants that are longer than the "minimum maximum" length specified in the C standard. Modern compilers generally allow string constants that are much longer than the standard's minimum limit, but very portable programs should avoid using longer strings.

  The limit applies *after* string constant concatenation, and does not count the trailing NUL. In C90, the limit was 509 characters; in C99, it was raised to 4095. C++98 does not specify a normative minimum maximum, so we do not diagnose overlength strings in C++.

  This option is implied by `-Wpedantic`, and can be disabled with `-Wno-overlength-strings`.

`-Wunsuffixed-float-constants` (C and Objective-C only)
: Issue a warning for any floating constant that does not have a suffix. When used together with `-Wsystem-headers` it warns about such constants in system header files. This can be useful when preparing code to use with the `FLOAT_CONST_DECIMAL64` pragma from the decimal floating-point extension to C99.

`-Wno-lto-type-mismatch`

During the link-time optimization, do not warn about type mismatches in global declarations from different compilation units. Requires `-flto` to be enabled. Enabled by default.

`-Wno-designated-init` (C and Objective-C only)

Suppress warnings when a positional initializer is used to initialize a structure that has been marked with the `designated_init` attribute.

3.10 Options That Control Static Analysis

`-fanalyzer`

This option enables an static analysis of program flow which looks for "interesting" interprocedural paths through the code, and issues warnings for problems found on them.

This analysis is much more expensive than other GCC warnings.

In technical terms, it performs coverage-guided symbolic execution of the code being compiled. It is neither sound nor complete: it can have false positives and false negatives. It is a bug-finding tool, rather than a tool for proving program correctness.

The analyzer is only suitable for use on C code in this release.

Enabling this option effectively enables the following warnings:

```
-Wanalyzer-allocation-size
-Wanalyzer-deref-before-check
-Wanalyzer-double-fclose
-Wanalyzer-double-free
-Wanalyzer-exposure-through-output-file
-Wanalyzer-exposure-through-uninit-copy
-Wanalyzer-fd-access-mode-mismatch
-Wanalyzer-fd-double-close
-Wanalyzer-fd-leak
-Wanalyzer-fd-phase-mismatch
-Wanalyzer-fd-type-mismatch
-Wanalyzer-fd-use-after-close
-Wanalyzer-fd-use-without-check
-Wanalyzer-file-leak
-Wanalyzer-free-of-non-heap
-Wanalyzer-imprecise-fp-arithmetic
-Wanalyzer-infinite-loop
-Wanalyzer-infinite-recursion
-Wanalyzer-jump-through-null
-Wanalyzer-malloc-leak
-Wanalyzer-mismatching-deallocation
-Wanalyzer-null-argument
-Wanalyzer-null-dereference
-Wanalyzer-out-of-bounds
-Wanalyzer-overlapping-buffers
-Wanalyzer-possible-null-argument
-Wanalyzer-possible-null-dereference
-Wanalyzer-putenv-of-auto-var
-Wanalyzer-shift-count-negative
-Wanalyzer-shift-count-overflow
```

```
-Wanalyzer-stale-setjmp-buffer
-Wanalyzer-tainted-allocation-size
-Wanalyzer-tainted-array-index
-Wanalyzer-tainted-assertion
-Wanalyzer-tainted-divisor
-Wanalyzer-tainted-offset
-Wanalyzer-tainted-size
-Wanalyzer-throw-of-unexpected-type
-Wanalyzer-undefined-behavior-ptrdiff
-Wanalyzer-undefined-behavior-strtok
-Wanalyzer-unsafe-call-within-signal-handler
-Wanalyzer-use-after-free
-Wanalyzer-use-of-pointer-in-stale-stack-frame
-Wanalyzer-use-of-uninitialized-value
-Wanalyzer-va-arg-type-mismatch
-Wanalyzer-va-list-exhausted
-Wanalyzer-va-list-leak
-Wanalyzer-va-list-use-after-va-end
-Wanalyzer-write-to-const
-Wanalyzer-write-to-string-literal
```

This option is only available if GCC was configured with analyzer support enabled.

`-Wanalyzer-symbol-too-complex`

If `-fanalyzer` is enabled, the analyzer uses various heuristics to attempt to track the state of memory, but these can be defeated by sufficiently complicated code.

By default, the analysis silently stops tracking values of expressions if they exceed the threshold defined by `--param analyzer-max-svalue-depth=`*value*, and falls back to an imprecise representation for such expressions. The `-Wanalyzer-symbol-too-complex` option warns if this occurs.

`-Wanalyzer-too-complex`

If `-fanalyzer` is enabled, the analyzer uses various heuristics to attempt to explore the control flow and data flow in the program, but these can be defeated by sufficiently complicated code.

By default, the analysis silently stops if the code is too complicated for the analyzer to fully explore and it reaches an internal limit. The `-Wanalyzer-too-complex` option warns if this occurs.

`-Wno-analyzer-allocation-size`

This warning requires `-fanalyzer`, which enables it; to disable it, use `-Wno-analyzer-allocation-size`.

This diagnostic warns for paths through the code in which a pointer to a buffer is assigned to point at a buffer with a size that is not a multiple of `sizeof (*pointer)`.

See CWE-131: Incorrect Calculation of Buffer Size (`https://cwe.mitre.org/data/definitions/131.html`).

`-Wno-analyzer-deref-before-check`

This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-deref-before-check` to disable it.

This diagnostic warns for paths through the code in which a pointer is checked for `NULL` *after* it has already been dereferenced, suggesting that the pointer could have been NULL. Such cases suggest that the check for NULL is either redundant, or that it needs to be moved to before the pointer is dereferenced.

This diagnostic also considers values passed to a function argument marked with `__attribute__((nonnull))` as requiring a non-NULL value, and thus will complain if such values are checked for `NULL` after returning from such a function call.

This diagnostic is unlikely to be reported when any level of optimization is enabled, as GCC's optimization logic will typically consider such checks for NULL as being redundant, and optimize them away before the analyzer "sees" them. Hence optimization should be disabled when attempting to trigger this diagnostic.

`-Wno-analyzer-double-fclose`

This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-double-fclose` to disable it.

This diagnostic warns for paths through the code in which a `FILE *` can have `fclose` called on it more than once.

See CWE-1341: Multiple Releases of Same Resource or Handle (`https://cwe.mitre.org/data/definitions/1341.html`).

`-Wno-analyzer-double-free`

This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-double-free` to disable it.

This diagnostic warns for paths through the code in which a pointer can have a deallocator called on it more than once, either `free`, or a deallocator referenced by attribute `malloc`.

See CWE-415: Double Free (`https://cwe.mitre.org/data/definitions/415.html`).

`-Wno-analyzer-exposure-through-output-file`

This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-exposure-through-output-file` to disable it.

This diagnostic warns for paths through the code in which a security-sensitive value is written to an output file (such as writing a password to a log file).

See CWE-532: Information Exposure Through Log Files (`https://cwe.mitre.org/data/definitions/532.html`).

`-Wanalyzer-exposure-through-uninit-copy`

This warning requires both `-fanalyzer` and the use of a plugin to specify a function that copies across a "trust boundary". Use `-Wno-analyzer-exposure-through-uninit-copy` to disable it.

This diagnostic warns for "infoleaks" - paths through the code in which uninitialized values are copied across a security boundary (such as code within an OS kernel that copies a partially-initialized struct on the stack to user space).

See CWE-200: Exposure of Sensitive Information to an Unauthorized Actor (`https://cwe.mitre.org/data/definitions/200.html`).

-Wno-analyzer-fd-access-mode-mismatch

This warning requires -fanalyzer, which enables it; use -Wno-analyzer-fd-access-mode-mismatch to disable it.

This diagnostic warns for paths through code in which a read on a write-only file descriptor is attempted, or vice versa.

This diagnostic also warns for code paths in a which a function with attribute fd_arg_read (N) is called with a file descriptor opened with O_WRONLY at referenced argument N or a function with attribute fd_arg_write (N) is called with a file descriptor opened with O_RDONLY at referenced argument *N*.

-Wno-analyzer-fd-double-close

This warning requires -fanalyzer, which enables it; use -Wno-analyzer-fd-double-close to disable it.

This diagnostic warns for paths through code in which a file descriptor can be closed more than once.

See CWE-1341: Multiple Releases of Same Resource or Handle (https://cwe.mitre.org/data/definitions/1341.html).

-Wno-analyzer-fd-leak

This warning requires -fanalyzer, which enables it; use -Wno-analyzer-fd-leak to disable it.

This diagnostic warns for paths through code in which an open file descriptor is leaked.

See CWE-775: Missing Release of File Descriptor or Handle after Effective Lifetime (https://cwe.mitre.org/data/definitions/775.html).

-Wno-analyzer-fd-phase-mismatch

This warning requires -fanalyzer, which enables it; use -Wno-analyzer-fd-phase-mismatch to disable it.

This diagnostic warns for paths through code in which an operation is attempted in the wrong phase of a file descriptor's lifetime. For example, it will warn on attempts to call accept on a stream socket that has not yet had listen successfully called on it.

See CWE-666: Operation on Resource in Wrong Phase of Lifetime (https://cwe.mitre.org/data/definitions/666.html).

-Wno-analyzer-fd-type-mismatch

This warning requires -fanalyzer, which enables it; use -Wno-analyzer-fd-type-mismatch to disable it.

This diagnostic warns for paths through code in which an operation is attempted on the wrong type of file descriptor. For example, it will warn on attempts to use socket operations on a file descriptor obtained via open, or when attempting to use a stream socket operation on a datagram socket.

-Wno-analyzer-fd-use-after-close

This warning requires -fanalyzer, which enables it; use -Wno-analyzer-fd-use-after-close to disable it.

This diagnostic warns for paths through code in which a read or write is called on a closed file descriptor.

This diagnostic also warns for paths through code in which a function with attribute `fd_arg (N)` or `fd_arg_read (N)` or `fd_arg_write (N)` is called with a closed file descriptor at referenced argument `N`.

`-Wno-analyzer-fd-use-without-check`
: This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-fd-use-without-check` to disable it.

  This diagnostic warns for paths through code in which a file descriptor is used without being checked for validity.

  This diagnostic also warns for paths through code in which a function with attribute `fd_arg (N)` or `fd_arg_read (N)` or `fd_arg_write (N)` is called with a file descriptor, at referenced argument `N`, without being checked for validity.

`-Wno-analyzer-file-leak`
: This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-file-leak` to disable it.

  This diagnostic warns for paths through the code in which a `<stdio.h> FILE *` stream object is leaked.

  See CWE-775: Missing Release of File Descriptor or Handle after Effective Lifetime (`https://cwe.mitre.org/data/definitions/775.html`).

`-Wno-analyzer-free-of-non-heap`
: This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-free-of-non-heap` to disable it.

  This diagnostic warns for paths through the code in which `free` is called on a non-heap pointer (e.g. an on-stack buffer, or a global).

  See CWE-590: Free of Memory not on the Heap (`https://cwe.mitre.org/data/definitions/590.html`).

`-Wno-analyzer-imprecise-fp-arithmetic`
: This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-imprecise-fp-arithmetic` to disable it.

  This diagnostic warns for paths through the code in which floating-point arithmetic is used in locations where precise computation is needed. This diagnostic only warns on use of floating-point operands inside the calculation of an allocation size at the moment.

`-Wno-analyzer-infinite-loop`
: This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-infinite-loop` to disable it.

  This diagnostics warns for paths through the code which appear to lead to an infinite loop.

  Specifically, the analyzer will issue this warning when it "sees" a loop in which:

  - no externally-visible work could be being done within the loop
  - there is no way to escape from the loop

- the analyzer is sufficiently confident about the program state throughout the loop to know that the above are true

One way for this warning to be emitted is when there is an execution path through a loop for which taking the path on one iteration implies that the same path will be taken on all subsequent iterations.

For example, consider:

```
while (1)
  {
    char opcode = *cpu_state.pc;
    switch (opcode)
     {
     case OPCODE_FOO:
       handle_opcode_foo (&cpu_state);
       break;
     case OPCODE_BAR:
       handle_opcode_bar (&cpu_state);
       break;
     }
  }
```

The analyzer will complain for the above case because if `opcode` ever matches none of the cases, the `switch` will follow the implicit `default` case, making the body of the loop be a "no-op" with `cpu_state.pc` unchanged, and thus using the same value of `opcode` on all subseqent iterations, leading to an infinite loop.

See CWE-835: Loop with Unreachable Exit Condition ('Infinite Loop') (`https://cwe.mitre.org/data/definitions/835.html`).

`-Wno-analyzer-infinite-recursion`

This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-infinite-recursion` to disable it.

This diagnostics warns for paths through the code which appear to lead to infinite recursion.

Specifically, when the analyzer "sees" a recursive call, it will compare the state of memory at the entry to the new frame with that at the entry to the previous frame of that function on the stack. The warning is issued if nothing in memory appears to be changing; any changes observed to parameters or globals are assumed to lead to termination of the recursion and thus suppress the warning.

This diagnostic is likely to miss cases of infinite recursion that are convered to iteration by the optimizer before the analyzer "sees" them. Hence optimization should be disabled when attempting to trigger this diagnostic.

Compare with `-Winfinite-recursion`, which provides a similar diagnostic, but is implemented in a different way.

See CWE-674: Uncontrolled Recursion (`https://cwe.mitre.org/data/definitions/674.html`).

`-Wno-analyzer-jump-through-null`

This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-jump-through-null` to disable it.

This diagnostic warns for paths through the code in which a `NULL` function pointer is called.

`-Wno-analyzer-malloc-leak`

This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-malloc-leak` to disable it.

This diagnostic warns for paths through the code in which a pointer allocated via an allocator is leaked: either `malloc`, or a function marked with attribute `malloc`.

See CWE-401: Missing Release of Memory after Effective Lifetime (`https://cwe.mitre.org/data/definitions/401.html`).

`-Wno-analyzer-mismatching-deallocation`

This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-mismatching-deallocation` to disable it.

This diagnostic warns for paths through the code in which the wrong deallocation function is called on a pointer value, based on which function was used to allocate the pointer value. The diagnostic will warn about mismatches between `free`, scalar `delete` and vector `delete[]`, and those marked as allocator/deallocator pairs using attribute `malloc`.

See CWE-762: Mismatched Memory Management Routines (`https://cwe.mitre.org/data/definitions/762.html`).

`-Wno-analyzer-out-of-bounds`

This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-out-of-bounds` to disable it.

This diagnostic warns for paths through the code in which a buffer is definitely read or written out-of-bounds. The diagnostic applies for cases where the analyzer is able to determine a constant offset and for accesses past the end of a buffer, also a constant capacity. Further, the diagnostic does limited checking for accesses past the end when the offset as well as the capacity is symbolic.

See CWE-119: Improper Restriction of Operations within the Bounds of a Memory Buffer (`https://cwe.mitre.org/data/definitions/119.html`).

For cases where the analyzer is able, it will emit a text art diagram visualizing the spatial relationship between the memory region that the analyzer predicts would be accessed, versus the range of memory that is valid to access: whether they overlap, are touching, are close or far apart; which one is before or after in memory, the relative sizes involved, the direction of the access (read vs write), and, in some cases, the values of data involved. This diagram can be suppressed using `-fdiagnostics-text-art-charset=none`.

`-Wno-analyzer-overlapping-buffers`

This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-overlapping-buffers` to disable it.

This diagnostic warns for paths through the code in which overlapping buffers are passed to an API for which the behavior on such buffers is undefined.

Specifically, the diagnostic occurs on calls to the following functions

- `memcpy`
- `strcat`

- `strcpy`

for cases where the buffers are known to overlap.

`-Wno-analyzer-possible-null-argument`
: This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-possible-null-argument` to disable it.

  This diagnostic warns for paths through the code in which a possibly-NULL value is passed to a function argument marked with `__attribute__ ((nonnull))` as requiring a non-NULL value.

  See CWE-690: Unchecked Return Value to NULL Pointer Dereference (`https://cwe.mitre.org/data/definitions/690.html`).

`-Wno-analyzer-possible-null-dereference`
: This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-possible-null-dereference` to disable it.

  This diagnostic warns for paths through the code in which a possibly-NULL value is dereferenced.

  See CWE-690: Unchecked Return Value to NULL Pointer Dereference (`https://cwe.mitre.org/data/definitions/690.html`).

`-Wno-analyzer-null-argument`
: This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-null-argument` to disable it.

  This diagnostic warns for paths through the code in which a value known to be NULL is passed to a function argument marked with `__attribute__ ((nonnull))` as requiring a non-NULL value.

  See CWE-476: NULL Pointer Dereference (`https://cwe.mitre.org/data/definitions/476.html`).

`-Wno-analyzer-null-dereference`
: This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-null-dereference` to disable it.

  This diagnostic warns for paths through the code in which a value known to be NULL is dereferenced.

  See CWE-476: NULL Pointer Dereference (`https://cwe.mitre.org/data/definitions/476.html`).

`-Wno-analyzer-putenv-of-auto-var`
: This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-putenv-of-auto-var` to disable it.

  This diagnostic warns for paths through the code in which a call to `putenv` is passed a pointer to an automatic variable or an on-stack buffer.

  See POS34-C. Do not call putenv() with a pointer to an automatic variable as the argument (`https://wiki.sei.cmu.edu/confluence/x/6NYxBQ`).

`-Wno-analyzer-shift-count-negative`
: This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-shift-count-negative` to disable it.

This diagnostic warns for paths through the code in which a shift is attempted with a negative count. It is analogous to the `-Wshift-count-negative` diagnostic implemented in the C/C++ front ends, but is implemented based on analyzing interprocedural paths, rather than merely parsing the syntax tree. However, the analyzer does not prioritize detection of such paths, so false negatives are more likely relative to other warnings.

`-Wno-analyzer-shift-count-overflow`

This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-shift-count-overflow` to disable it.

This diagnostic warns for paths through the code in which a shift is attempted with a count greater than or equal to the precision of the operand's type. It is analogous to the `-Wshift-count-overflow` diagnostic implemented in the C/C++ front ends, but is implemented based on analyzing interprocedural paths, rather than merely parsing the syntax tree. However, the analyzer does not prioritize detection of such paths, so false negatives are more likely relative to other warnings.

`-Wno-analyzer-stale-setjmp-buffer`

This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-stale-setjmp-buffer` to disable it.

This diagnostic warns for paths through the code in which `longjmp` is called to rewind to a `jmp_buf` relating to a `setjmp` call in a function that has returned.

When `setjmp` is called on a `jmp_buf` to record a rewind location, it records the stack frame. The stack frame becomes invalid when the function containing the `setjmp` call returns. Attempting to rewind to it via `longjmp` would reference a stack frame that no longer exists, and likely lead to a crash (or worse).

`-Wno-analyzer-tainted-allocation-size`

This warning requires `-fanalyzer` which enables it; use `-Wno-analyzer-tainted-allocation-size` to disable it.

This diagnostic warns for paths through the code in which a value that could be under an attacker's control is used as the size of an allocation without being sanitized, so that an attacker could inject an excessively large allocation and potentially cause a denial of service attack.

See CWE-789: Memory Allocation with Excessive Size Value (`https://cwe.mitre.org/data/definitions/789.html`).

`-Wno-analyzer-tainted-assertion`

This warning requires `-fanalyzer` which enables it; use `-Wno-analyzer-tainted-assertion` to disable it.

This diagnostic warns for paths through the code in which a value that could be under an attacker's control is used as part of a condition without being first sanitized, and that condition guards a call to a function marked with attribute `noreturn` (such as the function `__builtin_unreachable`). Such functions typically indicate abnormal termination of the program, such as for assertion failure handlers. For example:

```
assert (some_tainted_value < SOME_LIMIT);
```

In such cases:

- when assertion-checking is enabled: an attacker could trigger a denial of service by injecting an assertion failure
- when assertion-checking is disabled, such as by defining `NDEBUG`, an attacker could inject data that subverts the process, since it presumably violates a precondition that is being assumed by the code.

Note that when assertion-checking is disabled, the assertions are typically removed by the preprocessor before the analyzer has a chance to "see" them, so this diagnostic can only generate warnings on builds in which assertion-checking is enabled.

For the purpose of this warning, any function marked with attribute `noreturn` is considered as a possible assertion failure handler, including `__builtin_unreachable`. Note that these functions are sometimes removed by the optimizer before the analyzer "sees" them. Hence optimization should be disabled when attempting to trigger this diagnostic.

See CWE-617: Reachable Assertion (`https://cwe.mitre.org/data/definitions/617.html`).

The warning can also report problematic constructions such as

```
switch (some_tainted_value) {
case 0:
  /* [...etc; various valid cases omitted...] */
  break;

default:
  __builtin_unreachable (); /* BUG: attacker can trigger this  */
}
```

despite the above not being an assertion failure, strictly speaking.

`-Wno-analyzer-tainted-array-index`

This warning requires `-fanalyzer` which enables it; use `-Wno-analyzer-tainted-array-index` to disable it.

This diagnostic warns for paths through the code in which a value that could be under an attacker's control is used as the index of an array access without being sanitized, so that an attacker could inject an out-of-bounds access.

See CWE-129: Improper Validation of Array Index (`https://cwe.mitre.org/data/definitions/129.html`).

`-Wno-analyzer-tainted-divisor`

This warning requires `-fanalyzer` which enables it; use `-Wno-analyzer-tainted-divisor` to disable it.

This diagnostic warns for paths through the code in which a value that could be under an attacker's control is used as the divisor in a division or modulus operation without being sanitized, so that an attacker could inject a division-by-zero.

See CWE-369: Divide By Zero (`https://cwe.mitre.org/data/definitions/369.html`).

`-Wno-analyzer-tainted-offset`

This warning requires `-fanalyzer` which enables it; use `-Wno-analyzer-tainted-offset` to disable it.

This diagnostic warns for paths through the code in which a value that could be under an attacker's control is used as a pointer offset without being sanitized, so that an attacker could inject an out-of-bounds access.

See CWE-823: Use of Out-of-range Pointer Offset (`https://cwe.mitre.org/data/definitions/823.html`).

`-Wno-analyzer-tainted-size`

This warning requires `-fanalyzer` which enables it; use `-Wno-analyzer-tainted-size` to disable it.

This diagnostic warns for paths through the code in which a value that could be under an attacker's control is used as the size of an operation such as `memset` without being sanitized, so that an attacker could inject an out-of-bounds access.

See CWE-129: Improper Validation of Array Index (`https://cwe.mitre.org/data/definitions/129.html`).

`-Wno-analyzer-throw-of-unexpected-type`

This warning requires `-fanalyzer` which enables it; use `-Wno-analyzer-throw-of-unexpected-type` to disable it. Dynamic exception specifications are only available in C++14 and earlier.

This diagnostic warns for paths through the code in which a an exception is thrown from a function with a dynamic exception specification where the exception does not comply with the specification.

`-Wno-analyzer-undefined-behavior-ptrdiff`

This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-undefined-behavior-ptrdiff` to disable it.

This diagnostic warns for paths through the code in which a pointer subtraction occurs where the pointers refer to different chunks of memory. Such code relies on undefined behavior, as pointer subtraction is only defined for cases where both pointers point to within (or just after) the same array.

See CWE-469: Use of Pointer Subtraction to Determine Size (`https://cwe.mitre.org/data/definitions/469.html`).

`-Wno-analyzer-undefined-behavior-strtok`

This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-undefined-behavior-strtok` to disable it.

This diagnostic warns for paths through the code in which a call is made to `strtok` with undefined behavior.

Specifically, passing NULL as the first parameter for the initial call to `strtok` within a process has undefined behavior.

`-Wno-analyzer-unsafe-call-within-signal-handler`

This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-unsafe-call-within-signal-handler` to disable it.

This diagnostic warns for paths through the code in which a function known to be async-signal-unsafe (such as `fprintf`) is called from a signal handler.

See CWE-479: Signal Handler Use of a Non-reentrant Function (`https://cwe.mitre.org/data/definitions/479.html`).

`-Wno-analyzer-use-after-free`

This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-use-after-free` to disable it.

This diagnostic warns for paths through the code in which a pointer is used after a deallocator is called on it: either `free`, or a deallocator referenced by attribute `malloc`.

See CWE-416: Use After Free (`https://cwe.mitre.org/data/definitions/416.html`).

`-Wno-analyzer-use-of-pointer-in-stale-stack-frame`

This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-use-of-pointer-in-stale-stack-frame` to disable it.

This diagnostic warns for paths through the code in which a pointer is dereferenced that points to a variable in a stale stack frame.

`-Wno-analyzer-va-arg-type-mismatch`

This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-va-arg-type-mismatch` to disable it.

This diagnostic warns for interprocedural paths through the code for which the analyzer detects an attempt to use `va_arg` to extract a value passed to a variadic call, but uses a type that does not match that of the expression passed to the call.

See CWE-686: Function Call With Incorrect Argument Type (`https://cwe.mitre.org/data/definitions/686.html`).

`-Wno-analyzer-va-list-exhausted`

This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-va-list-exhausted` to disable it.

This diagnostic warns for interprocedural paths through the code for which the analyzer detects an attempt to use `va_arg` to access the next value passed to a variadic call, but all of the values in the `va_list` have already been consumed.

See CWE-685: Function Call With Incorrect Number of Arguments (`https://cwe.mitre.org/data/definitions/685.html`).

`-Wno-analyzer-va-list-leak`

This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-va-list-leak` to disable it.

This diagnostic warns for interprocedural paths through the code for which the analyzer detects that `va_start` or `va_copy` has been called on a `va_list` without a corresponding call to `va_end`.

`-Wno-analyzer-va-list-use-after-va-end`

This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-va-list-use-after-va-end` to disable it.

This diagnostic warns for interprocedural paths through the code for which the analyzer detects an attempt to use a `va_list` after `va_end` has been called on it. `va_list`.

`-Wno-analyzer-write-to-const`
: This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-write-to-const` to disable it.

  This diagnostic warns for paths through the code in which the analyzer detects an attempt to write through a pointer to a `const` object. However, the analyzer does not prioritize detection of such paths, so false negatives are more likely relative to other warnings.

`-Wno-analyzer-write-to-string-literal`
: This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-write-to-string-literal` to disable it.

  This diagnostic warns for paths through the code in which the analyzer detects an attempt to write through a pointer to a string literal. However, the analyzer does not prioritize detection of such paths, so false negatives are more likely relative to other warnings.

`-Wno-analyzer-use-of-uninitialized-value`
: This warning requires `-fanalyzer`, which enables it; use `-Wno-analyzer-use-of-uninitialized-value` to disable it.

  This diagnostic warns for paths through the code in which an uninitialized value is used.

  See CWE-457: Use of Uninitialized Variable (`https://cwe.mitre.org/data/definitions/457.html`).

The analyzer has hardcoded knowledge about the behavior of the following memory-management functions:

- `alloca`
- The built-in functions `__builtin_alloc`, `__builtin_alloc_with_align`,
- `__builtin_calloc`, `__builtin_free`, `__builtin_malloc`, `__builtin_memcpy`, `__builtin_memcpy_chk`, `__builtin_memset`, `__builtin_memset_chk`, `__builtin_realloc`, `__builtin_stack_restore`, and `__builtin_stack_save`
- `calloc`
- `free`
- `malloc`
- `memset`
- `operator delete`
- `operator delete []`
- `operator new`
- `operator new []`
- `realloc`
- `strdup`

- strndup

of the following functions for working with file descriptors:

- open
- close
- creat
- dup, dup2 and dup3
- isatty
- pipe, and pipe2
- read
- write
- socket, bind, listen, accept, and connect

of the following functions for working with <stdio.h> streams:

- The built-in functions __builtin_fprintf, __builtin_fprintf_unlocked, __builtin_fputc, __builtin_fputc_unlocked, __builtin_fputs, __builtin_fputs_unlocked, __builtin_fwrite, __builtin_fwrite_unlocked, __builtin_printf, __builtin_printf_unlocked, __builtin_putc, __builtin_putchar, __builtin_putchar_unlocked, __builtin_putc_unlocked, __builtin_puts, __builtin_puts_unlocked, __builtin_vfprintf, and __builtin_vprintf
- fopen
- fclose
- ferror
- fgets
- fgets_unlocked
- fileno
- fread
- getc
- getchar
- fprintf
- printf
- fwrite

and of the following functions:

- The built-in functions __builtin_expect, __builtin_expect_with_probability, __builtin_strchr, __builtin_strcpy, __builtin_strcpy_chk, __builtin_strlen, __builtin_va_copy, and __builtin_va_start
- The GNU extensions error and error_at_line
- getpass
- longjmp
- putenv
- setjmp

- `siglongjmp`
- `signal`
- `sigsetjmp`
- `strcat`
- `strchr`
- `strlen`

In addition, various functions with an `__analyzer_` prefix have special meaning to the analyzer, described in the GCC Internals manual.

Pertinent parameters for controlling the exploration are:

- `--param analyzer-bb-explosion-factor=`*`value`*
- `--param analyzer-max-enodes-per-program-point=`*`value`*
- `--param analyzer-max-recursion-depth=`*`value`*
- `--param analyzer-min-snodes-for-call-summary=`*`value`*

The following options control the analyzer.

`-fanalyzer-call-summaries`
: Simplify interprocedural analysis by computing the effect of certain calls, rather than exploring all paths through the function from callsite to each possible return.

  If enabled, call summaries are only used for functions with more than one call site, and that are sufficiently complicated (as per `--param analyzer-min-snodes-for-call-summary=`*`value`*).

`-fanalyzer-checker=`*`name`*
: Restrict the analyzer to run just the named checker, and enable it.

`-fanalyzer-debug-text-art-headings`
: This option is intended for analyzer developers. If enabled, the analyzer will add extra annotations to any diagrams it generates.

`-fno-analyzer-feasibility`
: This option is intended for analyzer developers.

  By default the analyzer verifies that there is a feasible control flow path for each diagnostic it emits: that the conditions that hold are not mutually exclusive. Diagnostics for which no feasible path can be found are rejected. This filtering can be suppressed with `-fno-analyzer-feasibility`, for debugging issues in this code.

`-fanalyzer-fine-grained`
: This option is intended for analyzer developers.

  Internally the analyzer builds an "exploded graph" that combines control flow graphs with data flow information.

  By default, an edge in this graph can contain the effects of a run of multiple statements within a basic block. With `-fanalyzer-fine-grained`, each statement gets its own edge.

`-fanalyzer-show-duplicate-count`

This option is intended for analyzer developers: if multiple diagnostics have been detected as being duplicates of each other, it emits a note when reporting the best diagnostic, giving the number of additional diagnostics that were suppressed by the deduplication logic.

`-fanalyzer-show-events-in-system-headers`

By default the analyzer emits simplified diagnostics paths by hiding events fully located within a system header. With `-fanalyzer-show-events-in-system-headers` such events are no longer suppressed.

`-fno-analyzer-state-merge`

This option is intended for analyzer developers.

By default the analyzer attempts to simplify analysis by merging sufficiently similar states at each program point as it builds its "exploded graph". With `-fno-analyzer-state-merge` this merging can be suppressed, for debugging state-handling issues.

`-fno-analyzer-state-purge`

This option is intended for analyzer developers.

By default the analyzer attempts to simplify analysis by purging aspects of state at a program point that appear to no longer be relevant e.g. the values of locals that aren't accessed later in the function and which aren't relevant to leak analysis.

With `-fno-analyzer-state-purge` this purging of state can be suppressed, for debugging state-handling issues.

`-fno-analyzer-suppress-followups`

This option is intended for analyzer developers.

By default the analyzer will stop exploring an execution path after encountering certain diagnostics, in order to avoid potentially issuing a cascade of follow-up diagnostics.

The diagnostics that terminate analysis along a path are:

- `-Wanalyzer-null-argument`
- `-Wanalyzer-null-dereference`
- `-Wanalyzer-use-after-free`
- `-Wanalyzer-use-of-pointer-in-stale-stack-frame`
- `-Wanalyzer-use-of-uninitialized-value`

With `-fno-analyzer-suppress-followups` the analyzer will continue to explore such paths even after such diagnostics, which may be helpful for debugging issues in the analyzer, or for microbenchmarks for detecting undefined behavior.

`-fanalyzer-transitivity`

This option enables transitivity of constraints within the analyzer.

`-fno-analyzer-undo-inlining`

This option is intended for analyzer developers.

`-fanalyzer` runs relatively late compared to other code analysis tools, and some optimizations have already been applied to the code. In particular function inlining may have occurred, leading to the interprocedural execution paths emitted by the analyzer containing function frames that don't correspond to those in the original source code.

By default the analyzer attempts to reconstruct the original function frames, and to emit events showing the inlined calls.

With `-fno-analyzer-undo-inlining` this attempt to reconstruct the original frame information can be disabled, which may be of help when debugging issues in the analyzer.

`-fanalyzer-verbose-edges`
: This option is intended for analyzer developers. It enables more verbose, lower-level detail in the descriptions of control flow within diagnostic paths.

`-fanalyzer-verbose-state-changes`
: This option is intended for analyzer developers. It enables more verbose, lower-level detail in the descriptions of events relating to state machines within diagnostic paths.

`-fanalyzer-verbosity=`*`level`*
: This option controls the complexity of the control flow paths that are emitted for analyzer diagnostics.

The *level* can be one of:

'`0`' At this level, interprocedural call and return events are displayed, along with the most pertinent state-change events relating to a diagnostic. For example, for a double-`free` diagnostic, both calls to `free` will be shown.

'`1`' As per the previous level, but also show events for the entry to each function.

'`2`' As per the previous level, but also show events relating to control flow that are significant to triggering the issue (e.g. "true path taken" at a conditional).

This level is the default.

'`3`' As per the previous level, but show all control flow events, not just significant ones.

'`4`' This level is intended for analyzer developers; it adds various other events intended for debugging the analyzer.

`-fdump-analyzer`
: Dump internal details about what the analyzer is doing to *`file`*`.analyzer.txt`. `-fdump-analyzer-stderr` overrides this option.

`-fdump-analyzer-stderr`
: Dump internal details about what the analyzer is doing to stderr. This option overrides `-fdump-analyzer`.

`-fdump-analyzer-callgraph`
: Dump a representation of the call graph suitable for viewing with GraphViz to *file*`.callgraph.dot`.

`-fdump-analyzer-exploded-graph`
: Dump a representation of the "exploded graph" suitable for viewing with GraphViz to *file*`.eg.dot`. Nodes are color-coded based on state-machine states to emphasize state changes.

`-fdump-analyzer-exploded-nodes`
: Emit diagnostics showing where nodes in the "exploded graph" are in relation to the program source.

`-fdump-analyzer-exploded-nodes-2`
: Dump a textual representation of the "exploded graph" to *file*`.eg.txt`.

`-fdump-analyzer-exploded-nodes-3`
: Dump a textual representation of the "exploded graph" to one dump file per node, to *file*`.eg-`*id*`.txt`. This is typically a large number of dump files.

`-fdump-analyzer-exploded-paths`
: Dump a textual representation of the "exploded path" for each diagnostic to *file*`.`*idx*`.`*kind*`.epath.txt`.

`-fdump-analyzer-feasibility`
: Dump internal details about the analyzer's search for feasible paths. The details are written in a form suitable for viewing with GraphViz to filenames of the form *file*`.*.fg.dot`, *file*`.*.tg.dot`, and *file*`.*.fpath.txt`.

`-fdump-analyzer-infinite-loop`
: Dump internal details about the analyzer's search for infinite loops. The details are written in a form suitable for viewing with GraphViz to filenames of the form *file*`.*.infinite-loop.dot`.

`-fdump-analyzer-json`
: Dump a compressed JSON representation of analyzer internals to *file*`.analyzer.json.gz`. The precise format is subject to change.

`-fdump-analyzer-state-purge`
: As per `-fdump-analyzer-supergraph`, dump a representation of the "supergraph" suitable for viewing with GraphViz, but annotate the graph with information on what state will be purged at each node. The graph is written to *file*`.state-purge.dot`.

`-fdump-analyzer-supergraph`
: Dump representations of the "supergraph" suitable for viewing with GraphViz to *file*`.supergraph.dot` and to *file*`.supergraph-eg.dot`. These show all of the control flow graphs in the program, with interprocedural edges for calls and returns. The second dump contains annotations showing nodes in the "exploded graph" and diagnostics associated with them.

`-fdump-analyzer-untracked`
: Emit custom warnings with internal details intended for analyzer developers.

3.11 Options for Debugging Your Program

To tell GCC to emit extra information for use by a debugger, in almost all cases you need only to add `-g` to your other options. Some debug formats can co-exist (like DWARF with CTF) when each of them is enabled explicitly by adding the respective command line option to your other options.

GCC allows you to use `-g` with `-O`. The shortcuts taken by optimized code may occasionally be surprising: some variables you declared may not exist at all; flow of control may briefly move where you did not expect it; some statements may not be executed because they compute constant results or their values are already at hand; some statements may execute in different places because they have been moved out of loops. Nevertheless it is possible to debug optimized output. This makes it reasonable to use the optimizer for programs that might have bugs.

If you are not using some other optimization option, consider using `-Og` (see Section 3.12 [Optimize Options], page 194) with `-g`. With no `-O` option at all, some compiler passes that collect information useful for debugging do not run at all, so that `-Og` may result in a better debugging experience.

`-g`
`--debug`
: Produce debugging information in the operating system's native format (stabs, COFF, XCOFF, or DWARF). GDB can work with this debugging information.

  On most systems that use stabs format, `-g` enables use of extra debugging information that only GDB can use; this extra information makes debugging work better in GDB but probably makes other debuggers crash or refuse to read the program. If you want to control for certain whether to generate the extra information, use `-gvms` (see below).

`-ggdb`
: Produce debugging information for use by GDB. This means to use the most expressive format available (DWARF, stabs, or the native format if neither of those are supported), including GDB extensions if at all possible.

`-gdwarf`
`-gdwarf-`*`version`*
: Produce debugging information in DWARF format (if that is supported). The value of *version* may be either 2, 3, 4 or 5; the default version for most targets is 5 (with the exception of VxWorks, TPF and Darwin / macOS, which default to version 2, and AIX, which defaults to version 4).

  Note that with DWARF Version 2, some ports require and always use some non-conflicting DWARF 3 extensions in the unwind tables.

  Version 4 may require GDB 7.0 and `-fvar-tracking-assignments` for maximum benefit. Version 5 requires GDB 8.0 or higher.

  GCC no longer supports DWARF Version 1, which is substantially different than Version 2 and later. For historical reasons, some other DWARF-related options such as `-fno-dwarf2-cfi-asm`) retain a reference to DWARF Version 2 in their names, but apply to all currently-supported versions of DWARF.

`-gbtf`
: Request BTF debug information. BTF is the default debugging format for the eBPF target. On other targets, like x86, BTF debug information can be gen-

erated along with DWARF debug information when both of the debug formats are enabled explicitly via their respective command line options.

`-gprune-btf`
`-gno-prune-btf`
: Prune BTF information before emission. When pruning, only type information for types used by global variables and file-scope functions will be emitted. If compiling for the BPF target with BPF CO-RE enabled, type information will also be emitted for types used in BPF CO-RE relocations. In addition, struct and union types which are only referred to via pointers from members of other struct or union types shall be pruned and replaced with BTF_KIND_FWD, as though those types were only present in the input as forward declarations.

  This option substantially reduces the size of produced BTF information, but at significant loss in the amount of detailed type information. It is primarily useful when compiling for the BPF target, to minimize the size of the resulting object, and to eliminate BTF information which is not immediately relevant to the BPF program loading process.

  This option is enabled by default for the BPF target when generating BTF information.

`-gctf`
`-gctf`*level*
: Request CTF debug information and use level to specify how much CTF debug information should be produced. If `-gctf` is specified without a value for level, the default level of CTF debug information is 2.

  CTF debug information can be generated along with DWARF debug information when both of the debug formats are enabled explicitly via their respective command line options.

  Level 0 produces no CTF debug information at all. Thus, `-gctf0` negates `-gctf`.

  Level 1 produces CTF information for tracebacks only. This includes callsite information, but does not include type information.

  Level 2 produces type information for entities (functions, data objects etc.) at file-scope or global-scope only.

`-gvms`
: Produce debugging information in Alpha/VMS debug format (if that is supported). This is the format used by DEBUG on Alpha/VMS systems.

`-gcodeview`
: Produce debugging information in CodeView debug format (if that is supported). This is the format used by Microsoft Visual C++ on Windows.

`-g`*level*
`-ggdb`*level*
`-gvms`*level*
: Request debugging information and also use *level* to specify how much information. The default level is 2.

  Level 0 produces no debug information at all. Thus, `-g0` negates `-g`.

Level 1 produces minimal information, enough for making backtraces in parts of the program that you don't plan to debug. This includes descriptions of functions and external variables, and line number tables, but no information about local variables.

Level 3 includes extra information, such as all the macro definitions present in the program. Some debuggers support macro expansion when you use `-g3`.

If you use multiple `-g` options, with or without level numbers, the last such option is the one that is effective.

`-gdwarf` does not accept a concatenated debug level, to avoid confusion with `-gdwarf-`*`level`*. Instead use an additional `-g`*`level`* option to change the debug level for DWARF.

`-fno-eliminate-unused-debug-symbols`
: By default, no debug information is produced for symbols that are not actually used. Use this option if you want debug information for all symbols.

`-femit-class-debug-always`
: Instead of emitting debugging information for a C++ class in only one object file, emit it in all object files using the class. This option should be used only with debuggers that are unable to handle the way GCC normally emits debugging information for classes because using this option increases the size of debugging information by as much as a factor of two.

`-fno-merge-debug-strings`
: Direct the linker to not merge together strings in the debugging information that are identical in different object files. Merging is not supported by all assemblers or linkers. Merging decreases the size of the debug information in the output file at the cost of increasing link processing time. Merging is enabled by default.

`-fdebug-prefix-map=`*`old`*`=`*`new`*
: When compiling files residing in directory *`old`*, record debugging information describing them as if the files resided in directory *`new`* instead. This can be used to replace a build-time path with an install-time path in the debug info. It can also be used to change an absolute path to a relative path by using `.` for *new*. This can give more reproducible builds, which are location independent, but may require an extra command to tell GDB where to find the source files. See also `-ffile-prefix-map` and `-fcanon-prefix-map`.

`-fvar-tracking`
: Run variable tracking pass. It computes where variables are stored at each position in code. Better debugging information is then generated (if the debugging information format supports this information).

  It is enabled by default when compiling with optimization (`-Os`, `-O`, `-O2`, ...), debugging information (`-g`) and the debug info format supports it.

`-fvar-tracking-assignments`
: Annotate assignments to user variables early in the compilation and attempt to carry the annotations over throughout the compilation all the way to the end, in

an attempt to improve debug information while optimizing. Use of `-gdwarf-4` is recommended along with it.

It can be enabled even if var-tracking is disabled, in which case annotations are created and maintained, but discarded at the end. By default, this flag is enabled together with `-fvar-tracking`, except when selective scheduling is enabled.

`-fvar-tracking-uninit`
`-fno-var-tracking-uninit`

Perform variable tracking and also mark uninitialized variables in the debug information. This flag is enabled by default by `-fvar-tracking`; it also implies `-fvar-tracking`. To do variable tracking without marking uninitialized variables, use `-fvar-tracking -fno-var-tracking-uninit`.

`-gsplit-dwarf`

If DWARF debugging information is enabled, separate as much debugging information as possible into a separate output file with the extension `.dwo`. This option allows the build system to avoid linking files with debug information. To be useful, this option requires a debugger capable of reading `.dwo` files.

`-gdwarf32`
`-gdwarf64`

If DWARF debugging information is enabled, the `-gdwarf32` selects the 32-bit DWARF format and the `-gdwarf64` selects the 64-bit DWARF format. The default is target specific, on most targets it is `-gdwarf32` though. The 32-bit DWARF format is smaller, but can't support more than 2GiB of debug information in any of the DWARF debug information sections. The 64-bit DWARF format allows larger debug information and might not be well supported by all consumers yet.

`-gdescribe-dies`

Add description attributes to some DWARF DIEs that have no name attribute, such as artificial variables, external references and call site parameter DIEs.

`-gpubnames`

Generate DWARF `.debug_pubnames` and `.debug_pubtypes` sections.

`-ggnu-pubnames`

Generate `.debug_pubnames` and `.debug_pubtypes` sections in a format suitable for conversion into a GDB index. This option is only useful with a linker that can produce GDB index version 7.

`-gno-pubnames`

Don't generate DWARF `.debug_pubnames` and `.debug_pubtypes` sections.

`-fdebug-types-section`

When using DWARF Version 4 or higher, type DIEs can be put into their own `.debug_types` section instead of making them part of the `.debug_info` section. It is more efficient to put them in a separate comdat section since the linker can then remove duplicates. But not all DWARF consumers support `.debug_types` sections yet and on some objects `.debug_types` produces larger instead of smaller debugging information.

`-grecord-gcc-switches`
`-gno-record-gcc-switches`

This switch causes the command-line options used to invoke the compiler that may affect code generation to be appended to the DW_AT_producer attribute in DWARF debugging information. The options are concatenated with spaces separating them from each other and from the compiler version. It is enabled by default. See also `-frecord-gcc-switches` for another way of storing compiler options into the object file.

`-gstrict-dwarf`

Disallow using extensions of later DWARF standard version than selected with `-gdwarf-`*`version`*. On most targets using non-conflicting DWARF extensions from later standard versions is allowed.

`-gno-strict-dwarf`

Allow using extensions of later DWARF standard version than selected with `-gdwarf-`*`version`*.

`-gas-loc-support`

Inform the compiler that the assembler supports `.loc` directives. It may then use them for the assembler to generate DWARF2+ line number tables.

This is generally desirable, because assembler-generated line-number tables are a lot more compact than those the compiler can generate itself.

This option will be enabled by default if, at GCC configure time, the assembler was found to support such directives.

`-gno-as-loc-support`

Force GCC to generate DWARF2+ line number tables internally, if DWARF2+ line number tables are to be generated.

`-gas-locview-support`

Inform the compiler that the assembler supports `view` assignment and reset assertion checking in `.loc` directives.

This option will be enabled by default if, at GCC configure time, the assembler was found to support them.

`-gno-as-locview-support`

Force GCC to assign view numbers internally, if `-gvariable-location-views` are explicitly requested.

`-gcolumn-info`
`-gno-column-info`

Emit location column information into DWARF debugging information, rather than just file and line. This option is enabled by default.

`-gstatement-frontiers`
`-gno-statement-frontiers`

This option causes GCC to create markers in the internal representation at the beginning of statements, and to keep them roughly in place throughout compilation, using them to guide the output of `is_stmt` markers in the line number table. This is enabled by default when compiling with optimization

(`-Os`, `-O1`, `-O2`, ...), and outputting DWARF 2 debug information at the normal level.

`-gvariable-location-views`
`-gvariable-location-views=incompat5`
`-gno-variable-location-views`

Augment variable location lists with progressive view numbers implied from the line number table. This enables debug information consumers to inspect state at certain points of the program, even if no instructions associated with the corresponding source locations are present at that point. If the assembler lacks support for view numbers in line number tables, this will cause the compiler to emit the line number table, which generally makes them somewhat less compact. The augmented line number tables and location lists are fully backward-compatible, so they can be consumed by debug information consumers that are not aware of these augmentations, but they won't derive any benefit from them either.

This is enabled by default when outputting DWARF 2 debug information at the normal level, as long as there is assembler support, `-fvar-tracking-assignments` is enabled and `-gstrict-dwarf` is not. When assembler support is not available, this may still be enabled, but it will force GCC to output internal line number tables, and if `-ginternal-reset-location-views` is not enabled, that will most certainly lead to silently mismatching location views.

There is a proposed representation for view numbers that is not backward compatible with the location list format introduced in DWARF 5, that can be enabled with `-gvariable-location-views=incompat5`. This option may be removed in the future, is only provided as a reference implementation of the proposed representation. Debug information consumers are not expected to support this extended format, and they would be rendered unable to decode location lists using it.

`-ginternal-reset-location-views`
`-gno-internal-reset-location-views`

Attempt to determine location views that can be omitted from location view lists. This requires the compiler to have very accurate insn length estimates, which isn't always the case, and it may cause incorrect view lists to be generated silently when using an assembler that does not support location view lists. The GNU assembler will flag any such error as a `view number mismatch`. This is only enabled on ports that define a reliable estimation function.

`-ginline-points`
`-gno-inline-points`

Generate extended debug information for inlined functions. Location view tracking markers are inserted at inlined entry points, so that address and view numbers can be computed and output in debug information. This can be enabled independently of location views, in which case the view numbers won't be output, but it can only be enabled along with statement frontiers, and it is only enabled by default if location views are enabled.

`-gz[=type]`
Produce compressed debug sections in DWARF format, if that is supported. If *type* is not given, the default type depends on the capabilities of the assembler and linker used. *type* may be one of '`none`' (don't compress debug sections), '`zlib`' (use zlib compression in ELF gABI format), or '`zstd`' (use zstd compression in ELF gABI format). If the linker doesn't support writing compressed debug sections, the option is rejected. Otherwise, if the assembler does not support them, `-gz` is silently ignored when producing object files.

`-femit-struct-debug-baseonly`
Emit debug information for struct-like types only when the base name of the compilation source file matches the base name of file in which the struct is defined.

This option substantially reduces the size of debugging information, but at significant potential loss in type information to the debugger. See `-femit-struct-debug-reduced` for a less aggressive option. See `-femit-struct-debug-detailed` for more detailed control.

This option works only with DWARF debug output.

`-femit-struct-debug-reduced`
Emit debug information for struct-like types only when the base name of the compilation source file matches the base name of file in which the type is defined, unless the struct is a template or defined in a system header.

This option significantly reduces the size of debugging information, with some potential loss in type information to the debugger. See `-femit-struct-debug-baseonly` for a more aggressive option. See `-femit-struct-debug-detailed` for more detailed control.

This option works only with DWARF debug output.

`-femit-struct-debug-detailed[=spec-list]`
Specify the struct-like types for which the compiler generates debug information. The intent is to reduce duplicate struct debug information between different object files within the same program.

This option is a detailed version of `-femit-struct-debug-reduced` and `-femit-struct-debug-baseonly`, which serves for most needs.

A specification has the syntax
['`dir:`'|'`ind:`']['`ord:`'|'`gen:`']('`any`'|'`sys`'|'`base`'|'`none`')

The optional first word limits the specification to structs that are used directly ('`dir:`') or used indirectly ('`ind:`'). A struct type is used directly when it is the type of a variable, member. Indirect uses arise through pointers to structs. That is, when use of an incomplete struct is valid, the use is indirect. An example is '`struct one direct; struct two * indirect;`'.

The optional second word limits the specification to ordinary structs ('`ord:`') or generic structs ('`gen:`'). Generic structs are a bit complicated to explain. For C++, these are non-explicit specializations of template classes, or non-template classes within the above. Other programming languages have generics, but `-femit-struct-debug-detailed` does not yet implement them.

The third word specifies the source files for those structs for which the compiler should emit debug information. The values '`none`' and '`any`' have the normal meaning. The value '`base`' means that the base of name of the file in which the type declaration appears must match the base of the name of the main compilation file. In practice, this means that when compiling `foo.c`, debug information is generated for types declared in that file and `foo.h`, but not other header files. The value '`sys`' means those types satisfying '`base`' or declared in system or compiler headers.

You may need to experiment to determine the best settings for your application.

The default is `-femit-struct-debug-detailed=all`.

This option works only with DWARF debug output.

`-fno-dwarf2-cfi-asm`
: Emit DWARF unwind info as compiler generated `.eh_frame` section instead of using GAS `.cfi_*` directives.

`-fno-eliminate-unused-debug-types`
: Normally, when producing DWARF output, GCC avoids producing debug symbol output for types that are nowhere used in the source file being compiled. Sometimes it is useful to have GCC emit debugging information for all types declared in a compilation unit, regardless of whether or not they are actually used in that compilation unit, for example if, in the debugger, you want to cast a value to a type that is not actually used in your program (but is declared). More often, however, this results in a significant amount of wasted space.

3.12 Options That Control Optimization

These options control various sorts of optimizations.

Without any optimization option, the compiler's goal is to reduce the cost of compilation and to make debugging produce the expected results. Statements are independent: if you stop the program with a breakpoint between statements, you can then assign a new value to any variable or change the program counter to any other statement in the function and get exactly the results you expect from the source code.

Turning on optimization flags makes the compiler attempt to improve the performance and/or code size at the expense of compilation time and possibly the ability to debug the program.

The compiler performs optimization based on the knowledge it has of the program. Compiling multiple files at once to a single output file mode allows the compiler to use information gained from all of the files when compiling each of them.

Not all optimizations are controlled directly by a flag. Only optimizations that have a flag are listed in this section.

Most optimizations are completely disabled at `-O0` or if an `-O` level is not set on the command line, even if individual optimization flags are specified. Similarly, `-Og` suppresses many optimization passes.

Depending on the target and how GCC was configured, a slightly different set of optimizations may be enabled at each `-O` level than those listed here. You can invoke GCC with `-Q --help=optimizers` to find out the exact set of optimizations that are enabled at each level. See Section 3.2 [Overall Options], page 34, for examples.

`-O`
`-O1`
`--optimize`

Optimize. Optimizing compilation takes somewhat more time, and a lot more memory for a large function.

With `-O`, the compiler tries to reduce code size and execution time, without performing any optimizations that take a great deal of compilation time.

`-O` is the recommended optimization level for large machine-generated code as a sensible balance between time taken to compile and memory use: higher optimization levels perform optimizations with greater algorithmic complexity than at `-O`.

`-O` turns on the following optimization flags:

```
-fauto-inc-dec
-fbranch-count-reg
-fcombine-stack-adjustments
-fcompare-elim
-fcprop-registers
-fdce
-fdefer-pop
-fdelayed-branch
-fdse
-fforward-propagate
-fguess-branch-probability
-fif-conversion
-fif-conversion2
-finline-functions-called-once
-fipa-modref
-fipa-profile
-fipa-pure-const
-fipa-reference
-fipa-reference-addressable
-fivopts
-fmerge-constants
-fmove-loop-invariants
-fmove-loop-stores
-fomit-frame-pointer
-freorder-blocks
-fshrink-wrap
-fshrink-wrap-separate
-fsplit-wide-types
-fssa-backprop
-fssa-phiopt
-ftree-bit-ccp
-ftree-ccp
-ftree-ch
-ftree-coalesce-vars
-ftree-copy-prop
-ftree-dce
-ftree-dominator-opts
-ftree-dse
-ftree-forwprop
-ftree-fre
```

```
-ftree-phiprop
-ftree-pta
-ftree-scev-cprop
-ftree-sink
-ftree-slsr
-ftree-sra
-ftree-ter
-funit-at-a-time
```

`-O2` Optimize even more. GCC performs nearly all supported optimizations that do not involve a space-speed tradeoff. As compared to `-O`, this option increases both compilation time and the performance of the generated code.

`-O2` turns on all optimization flags specified by `-O1`. It also turns on the following optimization flags:

```
-falign-functions  -falign-jumps
-falign-labels  -falign-loops
-fcaller-saves
-fcode-hoisting
-fcrossjumping
-fcse-follow-jumps  -fcse-skip-blocks
-fdelete-null-pointer-checks -fdep-fusion
-fdevirtualize  -fdevirtualize-speculatively
-fexpensive-optimizations
-ffinite-loops
-fgcse  -fgcse-lm
-fhoist-adjacent-loads
-finline-functions
-finline-small-functions
-findirect-inlining
-fipa-bit-cp  -fipa-cp  -fipa-icf
-fipa-ra  -fipa-sra  -fipa-vrp
-fisolate-erroneous-paths-dereference
-flra-remat
-foptimize-crc
-foptimize-sibling-calls
-foptimize-strlen
-fpartial-inlining
-fpeephole2
-freorder-blocks-algorithm=stc
-freorder-blocks-and-partition  -freorder-functions
-frerun-cse-after-loop
-fschedule-insns  -fschedule-insns2
-fsched-interblock  -fsched-spec
-fstore-merging
-fstrict-aliasing
-fthread-jumps
-ftree-builtin-call-dce
-ftree-loop-vectorize
-ftree-pre
-ftree-slp-vectorize
-ftree-switch-conversion  -ftree-tail-merge
-ftree-vrp
-fvect-cost-model=very-cheap
```

Please note the warning under `-fgcse` about invoking `-O2` on programs that use computed gotos.

-O3 Optimize yet more. -O3 turns on all optimizations specified by -O2 and also turns on the following optimization flags:

```
-fgcse-after-reload
-fipa-cp-clone
-floop-interchange
-floop-unroll-and-jam
-fpeel-loops
-fpredictive-commoning
-fsplit-loops
-fsplit-paths
-ftree-loop-distribution
-ftree-partial-pre
-funswitch-loops
-fvect-cost-model=dynamic
-fversion-loops-for-strides
```

-O0 Reduce compilation time and make debugging produce the expected results. This is the default.

At -O0, GCC completely disables most optimization passes; they are not run even if you explicitly enable them on the command line, or are listed by -Q --help=optimizers as being enabled by default. Many optimizations performed by GCC depend on code analysis or canonicalization passes that are enabled by -O, and it would not be useful to run individual optimization passes in isolation.

-Os Optimize for size. -Os enables all -O2 optimizations except those that often increase code size:

```
-falign-functions  -falign-jumps
-falign-labels  -falign-loops
-fprefetch-loop-arrays  -freorder-blocks-algorithm=stc
```

It also enables -finline-functions, causes the compiler to tune for code size rather than execution speed, and performs further optimizations designed to reduce code size.

-Ofast Disregard strict standards compliance. -Ofast enables all -O3 optimizations. It also enables optimizations that are not valid for all standard-compliant programs. It turns on -ffast-math, -fallow-store-data-races and the Fortran-specific -fstack-arrays, unless -fmax-stack-var-size is specified, and -fno-protect-parens. It turns off -fsemantic-interposition.

-Og Optimize while keeping in mind debugging experience. -Og should be the optimization level of choice for the standard edit-compile-debug cycle, offering a reasonable blend of optimization, fast compilation and debugging experience especially for code with a high abstraction penalty. In contrast to -O0, this enables -fvar-tracking-assignments and -fvar-tracking which handle debug information in the prologue and epilogue of functions better than -O0.

Like -O0, -Og completely skips a number of optimization passes so that individual options controlling them have no effect. Otherwise -Og enables all -O1 optimization flags except for those known to greatly interfere with debugging:

```
-fbranch-count-reg  -fdelayed-branch
-fdse  -fif-conversion  -fif-conversion2
-finline-functions-called-once
```

```
-fmove-loop-invariants  -fmove-loop-stores  -fssa-phiopt
-ftree-bit-ccp  -ftree-dse  -ftree-pta  -ftree-sra
```

`-Oz` Optimize aggressively for size rather than speed. This may increase the number of instructions executed if those instructions require fewer bytes to encode. `-Oz` behaves similarly to `-Os` including enabling most `-O2` optimizations.

If you use multiple `-O` options, with or without level numbers, the last such option is the one that is effective.

Options of the form `-f`*`flag`* specify machine-independent flags. Most flags have both positive and negative forms; the negative form of `-ffoo` is `-fno-foo`. In the table below, only one of the forms is listed—the one you typically use. You can figure out the other form by either removing '`no-`' or adding it.

The following options control specific optimizations. They are either activated by `-O` options or are related to ones that are. You can use the following flags in the rare cases when "fine-tuning" of optimizations to be performed is desired.

`-fno-defer-pop`

For machines that must pop arguments after a function call, always pop the arguments as soon as each function returns. At levels `-O1` and higher, `-fdefer-pop` is the default; this allows the compiler to let arguments accumulate on the stack for several function calls and pop them all at once.

`-fforward-propagate`

Perform a forward propagation pass on RTL. The pass tries to combine two instructions and checks if the result can be simplified. If loop unrolling is active, two passes are performed and the second is scheduled after loop unrolling.

This option is enabled by default at optimization levels `-O1`, `-O2`, `-O3`, `-Os`.

`-favoid-store-forwarding`
`-fno-avoid-store-forwarding`

Many CPUs will stall for many cycles when a load partially depends on previous smaller stores. This pass tries to detect such cases and avoid the penalty by changing the order of the load and store and then fixing up the loaded value.

Disabled by default.

`-ffp-contract=`*`style`*

`-ffp-contract=off` disables floating-point expression contraction. `-ffp-contract=fast` enables floating-point expression contraction such as forming of fused multiply-add operations if the target has native support for them. `-ffp-contract=on` enables floating-point expression contraction if allowed by the language standard. This is implemented for C and C++, where it enables contraction within one expression, but not across different statements.

The default is `-ffp-contract=off` for C in a standards compliant mode (`-std=c11` or similar), `-ffp-contract=fast` otherwise.

`-ffp-int-builtin-inexact`

Allow the built-in functions `ceil`, `floor`, `round` and `trunc`, and their `float` and `long double` variants, to generate code that raises the "inexact" floating-point exception for noninteger arguments. ISO C99 and C11 allow these functions to raise the "inexact" exception, but ISO/IEC TS 18661-1:2014, the C bindings to IEEE 754-2008, as integrated into ISO C23, does not allow these functions to do so.

The default is `-fno-fp-int-builtin-inexact`, disallowing the exception to be raised, unless C17 or an earlier C standard is selected. This option does nothing unless `-ftrapping-math` is in effect.

Even if `-fno-fp-int-builtin-inexact` is used, if the functions generate a call to a library function then the "inexact" exception may be raised if the library implementation does not follow TS 18661.

`-fomit-frame-pointer`
: Omit the frame pointer in functions that don't need one. This avoids the instructions to save, set up and restore the frame pointer; on many targets it also makes an extra register available.

On some targets this flag has no effect because the standard calling sequence always uses a frame pointer, so it cannot be omitted.

Note that `-fno-omit-frame-pointer` doesn't guarantee the frame pointer is used in all functions. Several targets always omit the frame pointer in leaf functions.

Enabled by default at `-O1` and higher.

`-foptimize-crc`
: Detect loops calculating CRC (performing polynomial long division) and replace them with a faster implementation. Detect 8, 16, 32, and 64 bit CRC, with a constant polynomial without the leading 1 bit, for both bit-forward and bit-reversed cases. If the target supports a CRC instruction and the polynomial used in the source code matches the polynomial used in the CRC instruction, generate that CRC instruction. Otherwise, if the target supports a carry-less-multiplication instruction, generate CRC using it; otherwise generate table-based CRC.

Enabled by default at `-O2` and higher.

`-foptimize-sibling-calls`
: Optimize sibling and tail recursive calls.

Enabled at levels `-O2`, `-O3`, `-Os`.

`-foptimize-strlen`
: Optimize various standard C string functions (e.g. `strlen`, `strchr` or `strcpy`) and their `_FORTIFY_SOURCE` counterparts into faster alternatives.

Enabled at levels `-O2`, `-O3`.

`-finline-atomics`
`-fno-inline-atomics`
: Inline '`__atomic`' operations when a lock-free instruction sequence is available. This optimization is enabled by default.

`-finline-stringops[=fn]`
Expand memory and string operations (for now, only `memset`) inline, even when the length is variable or big enough as to require looping. This is most useful along with `-ffreestanding` and `-fno-builtin`.

In some circumstances, it enables the compiler to generate code that takes advantage of known alignment and length multipliers, but even then it may be less efficient than optimized runtime implementations, and grow code size so much that even a less performant but shared implementation runs faster due to better use of code caches. This option is disabled by default.

`-fno-inline`
Do not expand any functions inline apart from those marked with the `always_inline` attribute. This is the default when not optimizing.

Single functions can be exempted from inlining by marking them with the `noinline` attribute.

`-finline-small-functions`
Integrate functions into their callers when their body is smaller than expected function call code (so overall size of program gets smaller). The compiler heuristically decides which functions are simple enough to be worth integrating in this way. This inlining applies to all functions, even those not declared inline.

Enabled at levels `-O2`, `-O3`, `-Os`.

`-findirect-inlining`
Inline also indirect calls that are discovered to be known at compile time thanks to previous inlining. This option has any effect only when inlining itself is turned on by the `-finline-functions` or `-finline-small-functions` options.

Enabled at levels `-O2`, `-O3`, `-Os`.

`-finline-functions`
Consider all functions for inlining, even if they are not declared inline. The compiler heuristically decides which functions are worth integrating in this way.

If all calls to a given function are integrated, and the function is declared `static`, then the function is normally not output as assembler code in its own right.

Enabled at levels `-O2`, `-O3`, `-Os`. Also enabled by `-fprofile-use` and `-fauto-profile`.

`-finline-functions-called-once`
Consider all `static` functions called once for inlining into their caller even if they are not marked `inline`. If a call to a given function is integrated, then the function is not output as assembler code in its own right.

Enabled at levels `-O1`, `-O2`, `-O3` and `-Os`, but not `-Og`.

`-fearly-inlining`
Inline functions marked by `always_inline` and functions whose body seems smaller than the function call overhead early before doing `-fprofile-generate` instrumentation and real inlining pass. Doing so makes profiling significantly

cheaper and usually inlining faster on programs having large chains of nested wrapper functions.

Enabled by default.

`-fipa-sra`

Perform interprocedural scalar replacement of aggregates, removal of unused parameters and replacement of parameters passed by reference by parameters passed by value.

Enabled at levels `-O2`, `-O3` and `-Os`.

`-finline-limit=n`

By default, GCC limits the size of functions that can be inlined. This flag allows coarse control of this limit. *n* is the size of functions that can be inlined in number of pseudo instructions.

Inlining is actually controlled by a number of parameters, which may be specified individually by using `--param name=value`. The `-finline-limit=n` option sets some of these parameters as follows:

`max-inline-insns-single`

is set to $n/2$.

`max-inline-insns-auto`

is set to $n/2$.

See below for a documentation of the individual parameters controlling inlining and for the defaults of these parameters.

Note: there may be no value to `-finline-limit` that results in default behavior.

Note: pseudo instruction represents, in this particular context, an abstract measurement of function's size. In no way does it represent a count of assembly instructions and as such its exact meaning might change from one release to an another.

`-fno-keep-inline-dllexport`

This is a more fine-grained version of `-fkeep-inline-functions`, which applies only to functions that are declared using the `dllexport` attribute or declspec. See Section 6.4.1 [Declaring Attributes of Functions], page 621.

`-fkeep-inline-functions`

In C, emit `static` functions that are declared `inline` into the object file, even if the function has been inlined into all of its callers. This switch does not affect functions using the `extern inline` extension in GNU C90. In C++, emit any and all inline functions into the object file.

`-fkeep-static-functions`

Emit `static` functions into the object file, even if the function is never used.

`-fkeep-static-consts`

Emit variables declared `static const` when optimization isn't turned on, even if the variables aren't referenced.

GCC enables this option by default. If you want to force the compiler to check if a variable is referenced, regardless of whether or not optimization is turned on, use the `-fno-keep-static-consts` option.

`-fmerge-constants`
: Attempt to merge identical constants (string constants and floating-point constants) across compilation units.

  This option is the default for optimized compilation if the assembler and linker support it. Use `-fno-merge-constants` to inhibit this behavior.

  Enabled at levels `-O1`, `-O2`, `-O3`, `-Os`.

`-fmerge-all-constants`
: Attempt to merge identical constants and identical variables.

  This option implies `-fmerge-constants`. In addition to `-fmerge-constants` this considers e.g. even constant initialized arrays or initialized constant variables with integral or floating-point types. Languages like C or C++ require each variable, including multiple instances of the same variable in recursive calls, to have distinct locations, so using this option results in non-conforming behavior.

`-fmodulo-sched`
: Perform swing modulo scheduling immediately before the first scheduling pass. This pass looks at innermost loops and reorders their instructions by overlapping different iterations.

`-fmodulo-sched-allow-regmoves`
: Perform more aggressive SMS-based modulo scheduling with register moves allowed. By setting this flag certain anti-dependences edges are deleted, which triggers the generation of reg-moves based on the life-range analysis. This option is effective only with `-fmodulo-sched` enabled.

`-fno-branch-count-reg`
: Disable the optimization pass that scans for opportunities to use "decrement and branch" instructions on a count register instead of instruction sequences that decrement a register, compare it against zero, and then branch based upon the result. This option is only meaningful on architectures that support such instructions, which include x86, PowerPC, IA-64 and S/390. Note that the `-fno-branch-count-reg` option doesn't remove the decrement and branch instructions from the generated instruction stream introduced by other optimization passes.

  The default is `-fbranch-count-reg` at `-O1` and higher, except for `-Og`.

`-fno-function-cse`
: Do not put function addresses in registers; make each instruction that calls a constant function contain the function's address explicitly.

  This option results in less efficient code, but some strange hacks that alter the assembler output may be confused by the optimizations performed when this option is not used.

  The default is `-ffunction-cse`

`-fno-zero-initialized-in-bss`
If the target supports a BSS section, GCC by default puts variables that are initialized to zero into BSS. This can save space in the resulting code.

This option turns off this behavior because some programs explicitly rely on variables going to the data section—e.g., so that the resulting executable can find the beginning of that section and/or make assumptions based on that.

The default is `-fzero-initialized-in-bss` except in Ada.

`-fthread-jumps`
Perform optimizations that check to see if a jump branches to a location where another comparison subsumed by the first is found. If so, the first branch is redirected to either the destination of the second branch or a point immediately following it, depending on whether the condition is known to be true or false.

Enabled at levels `-O1`, `-O2`, `-O3`, `-Os`.

`-fsplit-wide-types`
When using a type that occupies multiple registers, such as `long long` on a 32-bit system, split the registers apart and allocate them independently. This normally generates better code for those types, but may make debugging more difficult.

Enabled at levels `-O1`, `-O2`, `-O3`, `-Os`.

`-fsplit-wide-types-early`
Fully split wide types early, instead of very late. This option has no effect unless `-fsplit-wide-types` is turned on.

This is the default on some targets.

`-fcse-follow-jumps`
In common subexpression elimination (CSE), scan through jump instructions when the target of the jump is not reached by any other path. For example, when CSE encounters an `if` statement with an `else` clause, CSE follows the jump when the condition tested is false.

Enabled at levels `-O2`, `-O3`, `-Os`.

`-fcse-skip-blocks`
This is similar to `-fcse-follow-jumps`, but causes CSE to follow jumps that conditionally skip over blocks. When CSE encounters a simple `if` statement with no else clause, `-fcse-skip-blocks` causes CSE to follow the jump around the body of the `if`.

Enabled at levels `-O2`, `-O3`, `-Os`.

`-frerun-cse-after-loop`
Re-run common subexpression elimination after loop optimizations are performed.

Enabled at levels `-O2`, `-O3`, `-Os`.

`-fgcse`
Perform a global common subexpression elimination pass. This pass also performs global constant and copy propagation.

Note: When compiling a program using computed gotos, a GCC extension, you may get better run-time performance if you disable the global common subexpression elimination pass by adding `-fno-gcse` to the command line.

Enabled at levels `-O2`, `-O3`, `-Os`.

`-fgcse-lm`
: When `-fgcse-lm` is enabled, global common subexpression elimination attempts to move loads that are only killed by stores into themselves. This allows a loop containing a load/store sequence to be changed to a load outside the loop, and a copy/store within the loop.

  Enabled by default when `-fgcse` is enabled.

`-fgcse-sm`
: When `-fgcse-sm` is enabled, a store motion pass is run after global common subexpression elimination. This pass attempts to move stores out of loops. When used in conjunction with `-fgcse-lm`, loops containing a load/store sequence can be changed to a load before the loop and a store after the loop.

  Not enabled at any optimization level.

`-fgcse-las`
: When `-fgcse-las` is enabled, the global common subexpression elimination pass eliminates redundant loads that come after stores to the same memory location (both partial and full redundancies).

  Not enabled at any optimization level.

`-fgcse-after-reload`
: When `-fgcse-after-reload` is enabled, a redundant load elimination pass is performed after reload. The purpose of this pass is to clean up redundant spilling.

  Enabled by `-O3`, `-fprofile-use` and `-fauto-profile`.

`-faggressive-loop-optimizations`
: This option tells the loop optimizer to use language constraints to derive bounds for the number of iterations of a loop. This assumes that loop code does not invoke undefined behavior by for example causing signed integer overflows or out-of-bound array accesses. The bounds for the number of iterations of a loop are used to guide loop unrolling and peeling and loop exit test optimizations. This option is enabled by default.

`-funconstrained-commons`
: This option tells the compiler that variables declared in common blocks (e.g. Fortran) may later be overridden with longer trailing arrays. This prevents certain optimizations that depend on knowing the array bounds.

`-fcrossjumping`
: Perform cross-jumping transformation. This transformation unifies equivalent code and saves code size. The resulting code may or may not perform better than without cross-jumping.

  Enabled at levels `-O2`, `-O3`, `-Os`.

`-fauto-inc-dec`
: Combine increments or decrements of addresses with memory accesses. This pass is always skipped on architectures that do not have instructions to support this. Enabled by default at `-O1` and higher on architectures that support this.

`-fdce`
: Perform dead code elimination (DCE) on RTL. Enabled by default at `-O1` and higher.

`-fdse`
: Perform dead store elimination (DSE) on RTL. Enabled by default at `-O1` and higher.

`-fif-conversion`
: Attempt to transform conditional jumps into branch-less equivalents. This includes use of conditional moves, min, max, set flags and abs instructions, and some tricks doable by standard arithmetics. The use of conditional execution on chips where it is available is controlled by `-fif-conversion2`.

  Enabled at levels `-O1`, `-O2`, `-O3`, `-Os`, but not with `-Og`.

`-fif-conversion2`
: Use conditional execution (where available) to transform conditional jumps into branch-less equivalents.

  Enabled at levels `-O1`, `-O2`, `-O3`, `-Os`, but not with `-Og`.

`-fdeclone-ctor-dtor`
: The C++ ABI requires multiple entry points for constructors and destructors: one for a base subobject, one for a complete object, and one for a virtual destructor that calls operator delete afterwards. For a hierarchy with virtual bases, the base and complete variants are clones, which means two copies of the function. With this option, the base and complete variants are changed to be thunks that call a common implementation.

  Enabled by `-Os`.

`-fdelete-null-pointer-checks`
: Assume that programs cannot safely dereference null pointers, and that no code or data element resides at address zero. This option enables simple constant folding optimizations at all optimization levels. In addition, other optimization passes in GCC use this flag to control global dataflow analyses that eliminate useless checks for null pointers; these assume that a memory access to address zero always results in a trap, so that if a pointer is checked after it has already been dereferenced, it cannot be null.

  Note however that in some environments this assumption is not true. Use `-fno-delete-null-pointer-checks` to disable this optimization for programs that depend on that behavior.

  This option is enabled by default on most targets. On AVR and MSP430, this option is completely disabled.

  Passes that use the dataflow information are enabled independently at different optimization levels.

`-fdevirtualize`
Attempt to convert calls to virtual functions to direct calls. This is done both within a procedure and interprocedurally as part of indirect inlining (`-findirect-inlining`) and interprocedural constant propagation (`-fipa-cp`). Enabled at levels `-O2`, `-O3`, `-Os`.

`-fdevirtualize-speculatively`
Attempt to convert calls to virtual functions to speculative direct calls. Based on the analysis of the type inheritance graph, determine for a given call the set of likely targets. If the set is small, preferably of size 1, change the call into a conditional deciding between direct and indirect calls. The speculative calls enable more optimizations, such as inlining. When they seem useless after further optimization, they are converted back into original form.

`-fdevirtualize-at-ltrans`
Stream extra information needed for aggressive devirtualization when running the link-time optimizer in local transformation mode. This option enables more devirtualization but significantly increases the size of streamed data. For this reason it is disabled by default.

`-fexpensive-optimizations`
Perform a number of minor optimizations that are relatively expensive.

Enabled at levels `-O2`, `-O3`, `-Os`.

`-fext-dce`
`-fno-ext-dce`
Perform dead code elimination on zero and sign extensions, with special dataflow analysis.

`-free`
Attempt to remove redundant extension instructions. This is especially helpful for the x86-64 architecture, which implicitly zero-extends in 64-bit registers after writing to their lower 32-bit half.

Enabled for Alpha, AArch64, LoongArch, PowerPC, RISC-V, SPARC, h83000 and x86 at levels `-O2`, `-O3`, `-Os`.

`-fno-lifetime-dse`
In C++ the value of an object is only affected by changes within its lifetime: when the constructor begins, the object has an indeterminate value, and any changes during the lifetime of the object are dead when the object is destroyed. Normally dead store elimination will take advantage of this; if your code relies on the value of the object storage persisting beyond the lifetime of the object, you can use this flag to disable this optimization. To preserve stores before the constructor starts (e.g. because your operator new clears the object storage) but still treat the object as dead after the destructor, you can use `-flifetime-dse=1`. The default behavior can be explicitly selected with `-flifetime-dse=2`. `-flifetime-dse=0` is equivalent to `-fno-lifetime-dse`.

`-flive-range-shrinkage`
Attempt to decrease register pressure through register live range shrinkage. This is helpful for fast processors with small or moderate size register sets.

`-fira-algorithm=`*`algorithm`*
: Use the specified coloring algorithm for the integrated register allocator. The *algorithm* argument can be '`priority`', which specifies Chow's priority coloring, or '`CB`', which specifies Chaitin-Briggs coloring. Chaitin-Briggs coloring is not implemented for all architectures, but for those targets that do support it, it is the default because it generates better code.

`-fira-region=`*`region`*
: Use specified regions for the integrated register allocator. The *region* argument should be one of the following:

  '`all`' Use all loops as register allocation regions. This can give the best results for machines with a small and/or irregular register set.

  '`mixed`' Use all loops except for loops with small register pressure as the regions. This value usually gives the best results in most cases and for most architectures, and is enabled by default when compiling with optimization for speed (`-O`, `-O2`, ...).

  '`one`' Use all functions as a single region. This typically results in the smallest code size, and is enabled by default for `-Os` or `-O0`.

`-fira-hoist-pressure`
: Use IRA to evaluate register pressure in the code hoisting pass for decisions to hoist expressions. This option usually results in smaller code, but it can slow the compiler down.

  This option is enabled at level `-Os` for all targets.

`-fira-loop-pressure`
: Use IRA to evaluate register pressure in loops for decisions to move loop invariants. This option usually results in generation of faster and smaller code on machines with large register files (>= 32 registers), but it can slow the compiler down.

  This option is enabled at level `-O3` for some targets.

`-fno-ira-share-save-slots`
: Disable sharing of stack slots used for saving call-used hard registers living through a call. Each hard register gets a separate stack slot, and as a result function stack frames are larger.

`-fno-ira-share-spill-slots`
: Disable sharing of stack slots allocated for pseudo-registers. Each pseudo-register that does not get a hard register gets a separate stack slot, and as a result function stack frames are larger.

`-flra-remat`
: Enable CFG-sensitive rematerialization in LRA. Instead of loading values of spilled pseudos, LRA tries to rematerialize (recalculate) values if it is profitable.

  Enabled at levels `-O2`, `-O3`, `-Os`.

`-fdelayed-branch`
: If supported for the target machine, attempt to reorder instructions to exploit instruction slots available after delayed branch instructions.

Enabled at levels `-O1`, `-O2`, `-O3`, `-Os`, but not at `-Og`.

`-fschedule-insns`
: If supported for the target machine, attempt to reorder instructions to eliminate execution stalls due to required data being unavailable. This helps machines that have slow floating point or memory load instructions by allowing other instructions to be issued until the result of the load or floating-point instruction is required.

  Conventionally enabled at optimization levels `-O2` and `-O3`. However, many targets override this behavior. For example, on x86, it is disabled at all levels, while on AArch64, it is enabled only at `-O3`.

`-fschedule-insns2`
: Similar to `-fschedule-insns`, but requests an additional pass of instruction scheduling after register allocation has been done. This is especially useful on machines with a relatively small number of registers and where memory load instructions take more than one cycle.

  Enabled at levels `-O2`, `-O3`, `-Os`.

`-fno-sched-interblock`
: Disable instruction scheduling across basic blocks, which is normally enabled when scheduling before register allocation, i.e. with `-fschedule-insns` or at `-O2` or higher.

`-fno-sched-spec`
: Disable speculative motion of non-load instructions, which is normally enabled when scheduling before register allocation, i.e. with `-fschedule-insns` or at `-O2` or higher.

`-fsched-pressure`
: Enable register pressure sensitive insn scheduling before register allocation. This only makes sense when scheduling before register allocation is enabled, i.e. with `-fschedule-insns` or at `-O2` or higher. Usage of this option can improve the generated code and decrease its size by preventing register pressure increase above the number of available hard registers and subsequent spills in register allocation.

`-fsched-spec-load`
: Allow speculative motion of some load instructions. This only makes sense when scheduling before register allocation, i.e. with `-fschedule-insns` or at `-O2` or higher.

`-fsched-spec-load-dangerous`
: Allow speculative motion of more load instructions. This only makes sense when scheduling before register allocation, i.e. with `-fschedule-insns` or at `-O2` or higher.

`-fsched-stalled-insns`
`-fsched-stalled-insns=`*n*
: Define how many insns (if any) can be moved prematurely from the queue of stalled insns into the ready list during the second scheduling pass. `-fno-`

sched-stalled-insns means that no insns are moved prematurely, -fsched-stalled-insns=0 means there is no limit on how many queued insns can be moved prematurely. -fsched-stalled-insns without a value is equivalent to -fsched-stalled-insns=1.

-fsched-stalled-insns-dep
-fsched-stalled-insns-dep=*n*
: Define how many insn groups (cycles) are examined for a dependency on a stalled insn that is a candidate for premature removal from the queue of stalled insns. This has an effect only during the second scheduling pass, and only if -fsched-stalled-insns is used. -fno-sched-stalled-insns-dep is equivalent to -fsched-stalled-insns-dep=0. -fsched-stalled-insns-dep without a value is equivalent to -fsched-stalled-insns-dep=1.

-fsched2-use-superblocks
: When scheduling after register allocation, use superblock scheduling. This allows motion across basic block boundaries, resulting in faster schedules. This option is experimental, as not all machine descriptions used by GCC model the CPU closely enough to avoid unreliable results from the algorithm.

  This only makes sense when scheduling after register allocation, i.e. with -fschedule-insns2 or at -O2 or higher.

-fsched-group-heuristic
: Enable the group heuristic in the scheduler. This heuristic favors the instruction that belongs to a schedule group. This is enabled by default when scheduling is enabled, i.e. with -fschedule-insns or -fschedule-insns2 or at -O2 or higher.

-fsched-critical-path-heuristic
: Enable the critical-path heuristic in the scheduler. This heuristic favors instructions on the critical path. This is enabled by default when scheduling is enabled, i.e. with -fschedule-insns or -fschedule-insns2 or at -O2 or higher.

-fsched-spec-insn-heuristic
: Enable the speculative instruction heuristic in the scheduler. This heuristic favors speculative instructions with greater dependency weakness. This is enabled by default when scheduling is enabled, i.e. with -fschedule-insns or -fschedule-insns2 or at -O2 or higher.

-fsched-rank-heuristic
: Enable the rank heuristic in the scheduler. This heuristic favors the instruction belonging to a basic block with greater size or frequency. This is enabled by default when scheduling is enabled, i.e. with -fschedule-insns or -fschedule-insns2 or at -O2 or higher.

-fsched-last-insn-heuristic
: Enable the last-instruction heuristic in the scheduler. This heuristic favors the instruction that is less dependent on the last instruction scheduled. This is enabled by default when scheduling is enabled, i.e. with -fschedule-insns or -fschedule-insns2 or at -O2 or higher.

`-fsched-dep-count-heuristic`
: Enable the dependent-count heuristic in the scheduler. This heuristic favors the instruction that has more instructions depending on it. This is enabled by default when scheduling is enabled, i.e. with `-fschedule-insns` or `-fschedule-insns2` or at `-O2` or higher.

`-freschedule-modulo-scheduled-loops`
: Modulo scheduling is performed before traditional scheduling. If a loop is modulo scheduled, later scheduling passes may change its schedule. Use this option to control that behavior.

`-fselective-scheduling`
: Schedule instructions using selective scheduling algorithm. Selective scheduling runs instead of the first scheduler pass.

`-fselective-scheduling2`
: Schedule instructions using selective scheduling algorithm. Selective scheduling runs instead of the second scheduler pass.

`-fsel-sched-pipelining`
: Enable software pipelining of innermost loops during selective scheduling. This option has no effect unless one of `-fselective-scheduling` or `-fselective-scheduling2` is turned on.

`-fsel-sched-pipelining-outer-loops`
: When pipelining loops during selective scheduling, also pipeline outer loops. This option has no effect unless `-fsel-sched-pipelining` is turned on.

`-fsemantic-interposition`
: Some object formats, like ELF, allow interposing of symbols by the dynamic linker. This means that for symbols exported from the DSO, the compiler cannot perform interprocedural propagation, inlining and other optimizations in anticipation that the function or variable in question may change. While this feature is useful, for example, to rewrite memory allocation functions by a debugging implementation, it is expensive in the terms of code quality. With `-fno-semantic-interposition` the compiler assumes that if interposition happens for functions the overwriting function will have precisely the same semantics (and side effects). Similarly if interposition happens for variables, the constructor of the variable will be the same. The flag has no effect for functions explicitly declared inline (where it is never allowed for interposition to change semantics) and for symbols explicitly declared weak.

`-fshrink-wrap`
: Emit function prologues only before parts of the function that need it, rather than at the top of the function. This flag is enabled by default at `-O` and higher.

`-fshrink-wrap-separate`
: Shrink-wrap separate parts of the prologue and epilogue separately, so that those parts are only executed when needed. This option is on by default, but has no effect unless `-fshrink-wrap` is also turned on and the target supports this.

`-fcaller-saves`
: Enable allocation of values to registers that are clobbered by function calls, by emitting extra instructions to save and restore the registers around such calls. Such allocation is done only when it seems to result in better code.

  This option is always enabled by default on certain machines, usually those which have no call-preserved registers to use instead.

  Enabled at levels `-O2`, `-O3`, `-Os`.

`-fcombine-stack-adjustments`
: Tracks stack adjustments (pushes and pops) and stack memory references and then tries to find ways to combine them.

  Enabled by default at `-O1` and higher.

`-fipa-ra`
: Use caller save registers for allocation if those registers are not used by any called function. In that case it is not necessary to save and restore them around calls. This is only possible if called functions are part of same compilation unit as current function and they are compiled before it.

  Enabled at levels `-O2`, `-O3`, `-Os`, however the option is disabled if generated code will be instrumented for profiling (`-p`, or `-pg`) or if callee's register usage cannot be known exactly (this happens on targets that do not expose prologues and epilogues in RTL).

`-fconserve-stack`
: Attempt to minimize stack usage. The compiler attempts to use less stack space, even if that makes the program slower. This option implies setting the `large-stack-frame` parameter to 100 and the `large-stack-frame-growth` parameter to 400.

`-ftree-reassoc`
: Perform reassociation on trees. This flag is enabled by default at `-O1` and higher.

`-fcode-hoisting`
: Perform code hoisting. Code hoisting tries to move the evaluation of expressions executed on all paths to the function exit as early as possible. This is especially useful as a code size optimization, but it often helps for code speed as well. This flag is enabled by default at `-O2` and higher.

`-ftree-pre`
: Perform partial redundancy elimination (PRE) on trees. This flag is enabled by default at `-O2` and `-O3`.

`-ftree-partial-pre`
: Make partial redundancy elimination (PRE) more aggressive. This flag is enabled by default at `-O3`.

`-ftree-forwprop`
: Perform forward propagation on trees. This flag is enabled by default at `-O1` and higher.

-ftree-fre
: Perform full redundancy elimination (FRE) on trees. The difference between FRE and PRE is that FRE only considers expressions that are computed on all paths leading to the redundant computation. This analysis is faster than PRE, though it exposes fewer redundancies. This flag is enabled by default at `-O1` and higher.

-ftree-phiprop
: Perform hoisting of loads from conditional pointers on trees. This pass is enabled by default at `-O1` and higher.

-fhoist-adjacent-loads
: Speculatively hoist loads from both branches of an if-then-else if the loads are from adjacent locations in the same structure and the target architecture has a conditional move instruction. This flag is enabled by default at `-O2` and higher.

-ftree-copy-prop
: Perform copy propagation on trees. This pass eliminates unnecessary copy operations. This flag is enabled by default at `-O1` and higher.

-fipa-pure-const
: Discover which functions are pure or constant. Enabled by default at `-O1` and higher.

-fipa-reference
: Discover which static variables do not escape the compilation unit. Enabled by default at `-O1` and higher.

-fipa-reference-addressable
: Discover read-only, write-only and non-addressable static variables. Enabled by default at `-O1` and higher.

-fipa-reorder-for-locality
: Group call chains close together in the binary layout to improve code locality and minimize jump distances between frequently called functions. Unlike `-freorder-functions` this pass considers the call chains between functions and groups them together, rather than grouping all hot/normal/cold/never-executed functions into separate sections. Unlike `-fprofile-reorder-functions` it aims to improve code locality throughout the runtime of the program rather than focusing on program startup. This option is incompatible with an explicit `-flto-partition=` option since it enforces a custom partitioning scheme. If using this option it is recommended to also use profile feedback, but this option is not enabled by default otherwise.

-fipa-stack-alignment
: Reduce stack alignment on call sites if possible. Enabled by default.

-fipa-pta
: Perform interprocedural pointer analysis and interprocedural modification and reference analysis. This option can cause excessive memory and compile-time usage on large compilation units. It is not enabled by default at any optimization level.

`-fipa-profile`
Perform interprocedural profile propagation. The functions called only from cold functions are marked as cold. Also functions executed once (such as `cold`, `noreturn`, static constructors or destructors) are identified. Cold functions and loop less parts of functions executed once are then optimized for size. Enabled by default at `-O1` and higher.

`-fipa-modref`
Perform interprocedural mod/ref analysis. This optimization analyzes the side effects of functions (memory locations that are modified or referenced) and enables better optimization across the function call boundary. This flag is enabled by default at `-O1` and higher.

`-fipa-cp` Perform interprocedural constant propagation. This optimization analyzes the program to determine when values passed to functions are constants and then optimizes accordingly. This optimization can substantially increase performance if the application has constants passed to functions. This flag is enabled by default at `-O2`, `-Os` and `-O3`. It is also enabled by `-fprofile-use` and `-fauto-profile`.

`-fipa-cp-clone`
Perform function cloning to make interprocedural constant propagation stronger. When enabled, interprocedural constant propagation performs function cloning when externally visible function can be called with constant arguments. Because this optimization can create multiple copies of functions, it may significantly increase code size (see `--param ipa-cp-unit-growth=value`). This flag is enabled by default at `-O3`. It is also enabled by `-fprofile-use` and `-fauto-profile`.

`-fipa-bit-cp`
When enabled, perform interprocedural bitwise constant propagation. This flag is enabled by default at `-O2` and by `-fprofile-use` and `-fauto-profile`. It requires that `-fipa-cp` is enabled.

`-fipa-vrp`
When enabled, perform interprocedural propagation of value ranges. This flag is enabled by default at `-O2`. It requires that `-fipa-cp` is enabled.

`-fipa-icf-functions`
`-fipa-icf-variables`
`-fipa-icf`
Perform Identical Code Folding for functions (`-fipa-icf-functions`), read-only variables (`-fipa-icf-variables`), or both (`-fipa-icf`). The optimization reduces code size and may disturb unwind stacks by replacing a function by an equivalent one with a different name. The optimization works more effectively with link-time optimization enabled.

Although the behavior is similar to the Gold Linker's ICF optimization, GCC ICF works on different levels and thus the optimizations are not same - there are equivalences that are found only by GCC and equivalences found only by Gold.

`-fipa-icf` is enabled by default at `-O2` and `-Os`.

`-flate-combine-instructions`

Enable two instruction combination passes that run relatively late in the compilation process. One of the passes runs before register allocation and the other after register allocation. The main aim of the passes is to substitute definitions into all uses.

Most targets enable this flag by default at `-O2` and `-Os`.

`-flive-patching=`*`level`*

Control GCC's optimizations to produce output suitable for live-patching.

If the compiler's optimization uses a function's body or information extracted from its body to optimize/change another function, the latter is called an impacted function of the former. If a function is patched, its impacted functions should be patched too.

The impacted functions are determined by the compiler's interprocedural optimizations. For example, a caller is impacted when inlining a function into its caller, cloning a function and changing its caller to call this new clone, or extracting a function's pureness/constness information to optimize its direct or indirect callers, etc.

Usually, the more IPA optimizations enabled, the larger the number of impacted functions for each function. In order to control the number of impacted functions and more easily compute the list of impacted function, IPA optimizations can be partially enabled at two different levels.

The *level* argument should be one of the following:

'`inline-clone`'

Only enable inlining and cloning optimizations, which includes inlining, cloning, interprocedural scalar replacement of aggregates and partial inlining. As a result, when patching a function, all its callers and its clones' callers are impacted, therefore need to be patched as well.

`-flive-patching=inline-clone` disables the following optimization flags:

```
-fwhole-program  -fipa-pta  -fipa-reference  -fipa-ra
-fipa-icf  -fipa-icf-functions  -fipa-icf-variables
-fipa-bit-cp  -fipa-vrp  -fipa-pure-const
-fipa-reference-addressable
-fipa-stack-alignment -fipa-modref
```

'`inline-only-static`'

Only enable inlining of static functions. As a result, when patching a static function, all its callers are impacted and so need to be patched as well.

In addition to all the flags that `-flive-patching=inline-clone` disables, `-flive-patching=inline-only-static` disables the following additional optimization flags:

```
-fipa-cp-clone  -fipa-sra  -fpartial-inlining  -fipa-cp
```

When `-flive-patching` is specified without any value, the default value is *inline-clone*.

This flag is disabled by default.

Note that `-flive-patching` is not supported with link-time optimization (`-flto`).

`-fisolate-erroneous-paths-dereference`
: Detect paths that trigger erroneous or undefined behavior due to dereferencing a null pointer (with `-fdelete-null-pointer-checks` enabled) or a division by zero. Isolate those paths from the main control flow and turn the statement with erroneous or undefined behavior into a trap. This flag is enabled by default at `-O2` and higher.

`-fisolate-erroneous-paths-attribute`
: Detect paths that trigger erroneous or undefined behavior due to a null value being used in a way forbidden by a `returns_nonnull` or `nonnull` attribute. Isolate those paths from the main control flow and turn the statement with erroneous or undefined behavior into a trap. This is not currently enabled, but may be enabled by `-O2` in the future.

`-ftree-sink`
: Perform forward store motion on trees. This flag is enabled by default at `-O1` and higher.

`-ftree-bit-ccp`
: Perform sparse conditional bit constant propagation on trees and propagate pointer alignment information. This pass only operates on local scalar variables and is enabled by default at `-O1` and higher, except for `-Og`. It requires that `-ftree-ccp` is enabled.

`-ftree-ccp`
: Perform sparse conditional constant propagation (CCP) on trees. This pass only operates on local scalar variables and is enabled by default at `-O1` and higher.

`-fssa-backprop`
: Propagate information about uses of a value up the definition chain in order to simplify the definitions. For example, this pass strips sign operations if the sign of a value never matters. The flag is enabled by default at `-O1` and higher.

`-fssa-phiopt`
: Perform pattern matching on SSA PHI nodes to optimize conditional code. This pass is enabled by default at `-O1` and higher, except for `-Og`.

`-ftree-switch-conversion`
: Perform conversion of simple initializations in a switch to initializations from a scalar array. This flag is enabled by default at `-O2` and higher.

`-ftree-tail-merge`
: Look for identical code sequences. When found, replace one with a jump to the other. This optimization is known as tail merging or cross jumping. This

flag is enabled by default at `-O2` and higher. The compilation time in this pass can be limited using `max-tail-merge-comparisons` parameter and `max-tail-merge-iterations` parameter.

`-ftree-cselim`
: Perform conditional store elimination on trees. This flag is enabled by default at `-O1` and higher on targets that have conditional move instructions.

`-ftree-dce`
: Perform dead code elimination (DCE) on trees. This flag is enabled by default at `-O1` and higher.

`-ftree-builtin-call-dce`
: Perform conditional dead code elimination (DCE) for calls to built-in functions that may set `errno` but are otherwise free of side effects. This flag is enabled by default at `-O2` and higher if `-Os` is not also specified.

`-ffinite-loops`
: Assume that a loop with an exit will eventually take the exit and not loop indefinitely. This allows the compiler to remove loops that otherwise have no side-effects, not considering eventual endless looping as such.

  This option is enabled by default at `-O2` for C++ with -std=c++11 or higher.

`-ftree-dominator-opts`
: Perform a variety of simple scalar cleanups (constant/copy propagation, redundancy elimination, range propagation and expression simplification) based on a dominator tree traversal. This also performs jump threading (to reduce jumps to jumps). This flag is enabled by default at `-O1` and higher.

`-ftree-dse`
: Perform dead store elimination (DSE) on trees. A dead store is a store into a memory location that is later overwritten by another store without any intervening loads. In this case the earlier store can be deleted. This flag is enabled by default at `-O1` and higher.

`-ftree-ch`
: Perform loop header copying on trees. This is beneficial since it increases effectiveness of code motion optimizations. It also saves one jump. This flag is enabled by default at `-O1` and higher. It is not enabled for `-Os`, since it usually increases code size.

`-ftree-loop-optimize`
: Perform loop optimizations on trees. This flag is enabled by default at `-O1` and higher.

`-ftree-loop-linear`
`-floop-strip-mine`
`-floop-block`
: Perform loop nest optimizations. Same as `-floop-nest-optimize`. To use this code transformation, GCC has to be configured with `--with-isl` to enable the Graphite loop transformation infrastructure.

`-fgraphite-identity`

Enable the identity transformation for graphite. For every SCoP we generate the polyhedral representation and transform it back to gimple. Using `-fgraphite-identity` we can check the costs or benefits of the GIMPLE -> GRAPHITE -> GIMPLE transformation. Some minimal optimizations are also performed by the code generator isl, like index splitting and dead code elimination in loops.

`-floop-nest-optimize`

Enable the isl based loop nest optimizer. This is a generic loop nest optimizer based on the Pluto optimization algorithms. It calculates a loop structure optimized for data-locality and parallelism. This option is experimental.

`-floop-parallelize-all`

Use the Graphite data dependence analysis to identify loops that can be parallelized. Parallelize all the loops that can be analyzed to not contain loop carried dependences without checking that it is profitable to parallelize the loops.

`-ftree-coalesce-vars`

While transforming the program out of the SSA representation, attempt to reduce copying by coalescing versions of different user-defined variables, instead of just compiler temporaries. This may severely limit the ability to debug an optimized program compiled with `-fno-var-tracking-assignments`. In the negated form, this flag prevents SSA coalescing of user variables. This option is enabled by default if optimization is enabled, and it does very little otherwise.

`-ftree-loop-if-convert`

Attempt to transform conditional jumps in the innermost loops to branch-less equivalents. The intent is to remove control-flow from the innermost loops in order to improve the ability of the vectorization pass to handle these loops. This is enabled by default if vectorization is enabled.

`-ftree-loop-distribution`

Perform loop distribution. This flag can improve cache performance on big loop bodies and allow further loop optimizations, like parallelization or vectorization, to take place. For example, the loop

```
DO I = 1, N
  A(I) = B(I) + C
  D(I) = E(I) * F
ENDDO
```

is transformed to

```
DO I = 1, N
   A(I) = B(I) + C
ENDDO
DO I = 1, N
   D(I) = E(I) * F
ENDDO
```

This flag is enabled by default at `-O3`. It is also enabled by `-fprofile-use` and `-fauto-profile`.

`-ftree-loop-distribute-patterns`

Perform loop distribution of patterns that can be code generated with calls to a library. This flag is enabled by default at `-O2` and higher, and by `-fprofile-use` and `-fauto-profile`.

This pass distributes the initialization loops and generates a call to memset zero. For example, the loop

```
DO I = 1, N
  A(I) = 0
  B(I) = A(I) + I
ENDDO
```

is transformed to

```
DO I = 1, N
   A(I) = 0
ENDDO
DO I = 1, N
   B(I) = A(I) + I
ENDDO
```

and the initialization loop is transformed into a call to memset zero.

`-floop-interchange`

Perform loop interchange outside of graphite. This flag can improve cache performance on loop nest and allow further loop optimizations, like vectorization, to take place. For example, the loop

```
for (int i = 0; i < N; i++)
  for (int j = 0; j < N; j++)
    for (int k = 0; k < N; k++)
      c[i][j] = c[i][j] + a[i][k]*b[k][j];
```

is transformed to

```
for (int i = 0; i < N; i++)
  for (int k = 0; k < N; k++)
    for (int j = 0; j < N; j++)
      c[i][j] = c[i][j] + a[i][k]*b[k][j];
```

This flag is enabled by default at `-O3`. It is also enabled by `-fprofile-use` and `-fauto-profile`.

`-floop-unroll-and-jam`

Apply unroll and jam transformations on feasible loops. In a loop nest this unrolls the outer loop by some factor and fuses the resulting multiple inner loops. This flag is enabled by default at `-O3`. It is also enabled by `-fprofile-use` and `-fauto-profile`.

`-ftree-loop-im`

Perform loop invariant motion on trees. This pass moves only invariants that are hard to handle at RTL level (function calls, operations that expand to nontrivial sequences of insns). With `-funswitch-loops` it also moves operands of conditions that are invariant out of the loop, so that we can use just trivial invariantness analysis in loop unswitching. The pass also includes store motion.

`-ftree-loop-ivcanon`

Create a canonical counter for number of iterations in loops for which determining number of iterations requires complicated analysis. Later optimizations then may determine the number easily. Useful especially in connection with unrolling.

`-ftree-scev-cprop`
: Perform final value replacement. If a variable is modified in a loop in such a way that its value when exiting the loop can be determined using only its initial value and the number of loop iterations, replace uses of the final value by such a computation, provided it is sufficiently cheap. This reduces data dependencies and may allow further simplifications. Enabled by default at `-O1` and higher.

`-fivopts`
: Perform induction variable optimizations (strength reduction, induction variable merging and induction variable elimination) on trees. Enabled by default at `-O1` and higher.

`-ftree-parallelize-loops`
`-ftree-parallelize-loops=`*n*
: Parallelize loops, i.e., split their iteration space to run in multiple threads. This is only possible for loops whose iterations are independent and can be arbitrarily reordered. The optimization is only profitable on multiprocessor machines, for loops that are CPU-intensive, rather than constrained e.g. by memory bandwidth. This option implies `-pthread`, and thus is only supported on targets that have support for `-pthread`.

  When a positive value *n* is specified, the number of threads is fixed at compile time and cannot be changed after compilation. The compiler generates "#pragma omp parallel num_threads(*n*)".

  When used without `=`*n* (i.e., `-ftree-parallelize-loops`), the number of threads is determined at program execution time via the `OMP_NUM_THREADS` environment variable. If `OMP_NUM_THREADS` is not set, the OpenMP runtime automatically detects the number of available processors and uses that value. This enables creating binaries that adapt to different hardware configurations without recompilation.

`-ftree-pta`
: Perform function-local points-to analysis on trees. This flag is enabled by default at `-O1` and higher, except for `-Og`.

`-ftree-sra`
: Perform scalar replacement of aggregates. This pass replaces structure references with scalars to prevent committing structures to memory too early. This flag is enabled by default at `-O1` and higher, except for `-Og`.

`-fstore-merging`
: Perform merging of narrow stores to consecutive memory addresses. This pass merges contiguous stores of immediate values narrower than a word into fewer wider stores to reduce the number of instructions. This is enabled by default at `-O2` and higher as well as `-Os`.

`-ftree-ter`
: Perform temporary expression replacement during the SSA->normal phase. Single use/single def temporaries are replaced at their use location with their defining expression. This results in non-GIMPLE code, but gives the expanders

much more complex trees to work on resulting in better RTL generation. This is enabled by default at `-O1` and higher.

`-ftree-slsr`
: Perform straight-line strength reduction on trees. This recognizes related expressions involving multiplications and replaces them by less expensive calculations when possible. This is enabled by default at `-O1` and higher.

`-ftree-vectorize`
: Perform vectorization on trees. This flag enables `-ftree-loop-vectorize` and `-ftree-slp-vectorize` if not explicitly specified.

`-ftree-loop-vectorize`
: Perform loop vectorization on trees. This flag is enabled by default at `-O2` and by `-ftree-vectorize`, `-fprofile-use`, and `-fauto-profile`.

`-ftree-slp-vectorize`
: Perform basic block vectorization on trees. This flag is enabled by default at `-O2` and by `-ftree-vectorize`, `-fprofile-use`, and `-fauto-profile`.

`-ftrivial-auto-var-init=`*`choice`*
: Initialize automatic variables or temporary objects with either a pattern or with zeroes to increase the security and predictability of a program by preventing uninitialized memory disclosure and use. GCC still considers an automatic variable that doesn't have an explicit initializer as uninitialized, `-Wuninitialized` and `-Wanalyzer-use-of-uninitialized-value` will still report warning messages on such automatic variables or temporary objects and the compiler will perform optimization as if the variable were uninitialized. With this option, GCC will also initialize any padding of automatic variables or temporary objects that have structure or union types to zeroes. However, the current implementation cannot initialize automatic variables whose initialization is bypassed through `switch` or `goto` statement. Using `-Wtrivial-auto-var-init` to report all such cases.

The three values of *choice* are:

- '`uninitialized`' doesn't initialize any automatic variables.
- '`pattern`' Initialize automatic variables with values which will likely transform logic bugs into crashes down the line, are easily recognized in a crash dump and without being values that programmers can rely on for useful program semantics. The current value is byte-repeatable pattern with byte "0xFE". The values used for pattern initialization might be changed in the future.
- '`zero`' Initialize automatic variables with zeroes.

The default is '`uninitialized`' except for C++26, in which case if `-ftrivial-auto-var-init=` is not specified at all automatic variables or temporary objects are zero initialized, but zero initialization of padding bits does not happen.

Note that the initializer values, whether '`zero`' or '`pattern`', refer to data representation (in memory or machine registers), rather than to their interpretation as numerical values. This distinction may be important in languages that support types with biases or implicit multipliers, and with such extensions as 'hardbool' (see Section 6.4.3 [Type Attributes], page 715). For example, a variable that uses 8 bits to represent (biased) quantities in the range 160..400 will be initialized with the bit patterns 0x00 or 0xFE, depending on *choice*, whether or not these representations stand for values in that range, and even if they do, the interpretation of the value held by the variable will depend on the bias. A 'hardbool' variable that uses say 0x5A and 0xA5 for false and true, respectively, will trap with either 'choice' of trivial initializer, i.e., 'zero' initialization will not convert to the representation for false, even if it would for a static variable of the same type. This means the initializer pattern doesn't generally depend on the type of the initialized variable. One notable exception is that (non-hardened) boolean variables that fit in registers are initialized with false (zero), even when 'pattern' is requested.

You can control this behavior for a specific variable by using the variable attribute uninitialized standard attribute (see Section 6.4.2 [Variable Attributes], page 699) or the C++26 [[indeterminate]].

-fvect-cost-model=*model*

Alter the cost model used for vectorization. The *model* argument should be one of 'unlimited', 'dynamic', 'cheap' or 'very-cheap'. With the 'unlimited' model the vectorized code-path is assumed to be profitable while with the 'dynamic' model a runtime check guards the vectorized code-path to enable it only for iteration counts that will likely execute faster than when executing the original scalar loop. The 'cheap' model disables vectorization of loops where doing so would be cost prohibitive for example due to required runtime checks for data dependence or alignment but otherwise is equal to the 'dynamic' model. The 'very-cheap' model disables vectorization of loops when any runtime check for data dependence or alignment is required, it also disables vectorization of epilogue loops but otherwise is equal to the 'cheap' model.

The default cost model depends on other optimization flags and is either 'dynamic' or 'cheap'.

-fsimd-cost-model=*model*

Alter the cost model used for vectorization of loops marked with the OpenMP simd directive. The *model* argument should be one of 'unlimited', 'dynamic', 'cheap'. All values of *model* have the same meaning as described in -fvect-cost-model and by default a cost model defined with -fvect-cost-model is used.

-ftree-vrp

Perform Value Range Propagation on trees. This is similar to the constant propagation pass, but instead of values, ranges of values are propagated. This allows the optimizers to remove unnecessary range checks like array bound checks and null pointer checks. This is enabled by default at -O2 and higher. Null pointer check elimination is only done if -fdelete-null-pointer-checks is enabled.

`-fsplit-paths`
: Split paths leading to loop backedges. This can improve dead code elimination and common subexpression elimination. This is enabled by default at `-O3` and above.

`-fsplit-ivs-in-unroller`
: Enables expression of values of induction variables in later iterations of the unrolled loop using the value in the first iteration. This breaks long dependency chains, thus improving efficiency of the scheduling passes.

  A combination of `-fweb` and CSE is often sufficient to obtain the same effect. However, that is not reliable in cases where the loop body is more complicated than a single basic block. It also does not work at all on some architectures due to restrictions in the CSE pass.

  This optimization is enabled by default.

`-fvariable-expansion-in-unroller`
: With this option, the compiler creates multiple copies of some local variables when unrolling a loop, which can result in superior code.

  This optimization is enabled by default for PowerPC targets, but disabled by default otherwise.

`-fpartial-inlining`
: Inline parts of functions. This option has any effect only when inlining itself is turned on by the `-finline-functions` or `-finline-small-functions` options.

  Enabled at levels `-O2`, `-O3`, `-Os`.

`-fpredictive-commoning`
: Perform predictive commoning optimization, i.e., reusing computations (especially memory loads and stores) performed in previous iterations of loops.

  This option is enabled at level `-O3`. It is also enabled by `-fprofile-use` and `-fauto-profile`.

`-fprefetch-loop-arrays`
: If supported by the target machine, generate instructions to prefetch memory to improve the performance of loops that access large arrays.

  This option may generate better or worse code; results are highly dependent on the structure of loops within the source code.

  Disabled at level `-Os`.

`-fno-printf-return-value`
: Do not substitute constants for known return value of formatted output functions such as `sprintf`, `snprintf`, `vsprintf`, and `vsnprintf` (but not `printf` of `fprintf`). This transformation allows GCC to optimize or even eliminate branches based on the known return value of these functions called with arguments that are either constant, or whose values are known to be in a range that makes determining the exact return value possible. For example, when `-fprintf-return-value` is in effect, both the branch and the body of the `if` statement (but not the call to `snprint`) can be optimized away when `i` is a

32-bit or smaller integer because the return value is guaranteed to be at most 8.

```
char buf[9];
if (snprintf (buf, "%08x", i) >= sizeof buf)
  ...
```

The `-fprintf-return-value` option relies on other optimizations and yields best results with `-O2` and above. It works in tandem with the `-Wformat-overflow` and `-Wformat-truncation` options. The `-fprintf-return-value` option is enabled by default.

`-fno-peephole`
`-fno-peephole2`
Disable any machine-specific peephole optimizations. The difference between `-fno-peephole` and `-fno-peephole2` is in how they are implemented in the compiler; some targets use one, some use the other, a few use both.

`-fpeephole` is enabled by default. `-fpeephole2` enabled at levels `-O2`, `-O3`, `-Os`.

`-fno-guess-branch-probability`
Do not guess branch probabilities using heuristics.

GCC uses heuristics to guess branch probabilities if they are not provided by profiling feedback (`-fprofile-arcs`). These heuristics are based on the control flow graph. If some branch probabilities are specified by `__builtin_expect`, then the heuristics are used to guess branch probabilities for the rest of the control flow graph, taking the `__builtin_expect` info into account. The interactions between the heuristics and `__builtin_expect` can be complex, and in some cases, it may be useful to disable the heuristics so that the effects of `__builtin_expect` are easier to understand.

It is also possible to specify expected probability of the expression with `__builtin_expect_with_probability` built-in function.

The default is `-fguess-branch-probability` at levels `-O`, `-O2`, `-O3`, `-Os`.

`-freorder-blocks`
Reorder basic blocks in the compiled function in order to reduce number of taken branches and improve code locality.

Enabled at levels `-O1`, `-O2`, `-O3`, `-Os`.

`-freorder-blocks-algorithm=`*`algorithm`*
Use the specified algorithm for basic block reordering. The *algorithm* argument can be '`simple`', which does not increase code size (except sometimes due to secondary effects like alignment), or '`stc`', the "software trace cache" algorithm, which tries to put all often executed code together, minimizing the number of branches executed by making extra copies of code.

The default is '`simple`' at levels `-O1`, `-Os`, and '`stc`' at levels `-O2`, `-O3`.

`-freorder-blocks-and-partition`
In addition to reordering basic blocks in the compiled function, in order to reduce number of taken branches, partitions hot and cold basic blocks into

separate sections of the assembly and `.o` files, to improve paging and cache locality performance.

This optimization is automatically turned off in the presence of exception handling or unwind tables (on targets using setjump/longjump or target specific scheme), for linkonce sections, for functions with a user-defined section attribute and on any architecture that does not support named sections. When `-fsplit-stack` is used this option is not enabled by default (to avoid linker errors), but may be enabled explicitly (if using a working linker).

Enabled for x86 at levels `-O2`, `-O3`, `-Os`.

`-freorder-functions`

Reorder functions in the object file in order to improve code locality. Unlike `-fipa-reorder-for-locality` this option prioritises grouping all functions within a category (hot/normal/cold/never-executed) together. This is implemented by using special subsections `.text.hot` for most frequently executed functions and `.text.unlikely` for unlikely executed functions. Reordering is done by the linker so object file format must support named sections and linker must place them in a reasonable way.

This option isn't effective unless you either provide profile feedback (see `-fprofile-arcs` for details) or manually annotate functions with `hot` or `cold` attributes (see Section 6.4.1.1 [Common Function Attributes], page 622).

Enabled at levels `-O2`, `-O3`, `-Os`.

`-fstrict-aliasing`

Allow the compiler to assume the strictest aliasing rules applicable to the language being compiled. For C (and C++), this activates optimizations based on the type of expressions. In particular, accessing an object of one type via an expression of a different type is not allowed, unless the types are *compatible types*, differ only in signedness or qualifiers, or the expression has a character type. Accessing scalar objects via a corresponding vector type is also allowed.

For example, an `unsigned int` can alias an `int`, but not a `void*` or a `double`. A character type may alias any other type.

Pay special attention to code like this:

```
union a_union {
  int i;
  double d;
};

int f() {
  union a_union t;
  t.d = 3.0;
  return t.i;
}
```

The practice of reading from a different union member than the one most recently written to (called "type-punning") is common. Even with `-fstrict-aliasing`, type-punning is allowed in C, provided the memory is accessed through the union type. In ISO C++, type-punning through a union type is undefined behavior, but GCC supports it as an extension. So, the code above works as expected. See Section 4.10 [Structures unions enumerations and bit-fields implementation], page 596. However, this code might not:

```
int f() {
  union a_union t;
  int* ip;
  t.d = 3.0;
  ip = &t.i;
  return *ip;
}
```

Similarly, access by taking the address, casting the resulting pointer and dereferencing the result has undefined behavior, even if the cast uses a union type, e.g.:

```
int f() {
  double d = 3.0;
  return ((union a_union *) &d)->i;
}
```

The `-fstrict-aliasing` option is enabled at levels `-O2`, `-O3`, `-Os`.

`-fipa-strict-aliasing`

Controls whether rules of `-fstrict-aliasing` are applied across function boundaries. Note that if multiple functions gets inlined into a single function the memory accesses are no longer considered to be crossing a function boundary.

The `-fipa-strict-aliasing` option is enabled by default and is effective only in combination with `-fstrict-aliasing`.

`-falign-functions`
`-falign-functions=`*n*
`-falign-functions=`*n*`:`*m*
`-falign-functions=`*n*`:`*m*`:`*n2*
`-falign-functions=`*n*`:`*m*`:`*n2*`:`*m2*

Align the start of functions to the next power-of-two greater than or equal to *n*, skipping up to *m*-1 bytes. This ensures that at least the first *m* bytes of the function can be fetched by the CPU without crossing an *n*-byte alignment boundary. This is an optimization of code performance and alignment is ignored for functions considered cold. If alignment is required for all functions, use `-fmin-function-alignment`.

If *m* is not specified, it defaults to *n*.

Examples: `-falign-functions=32` aligns functions to the next 32-byte boundary, `-falign-functions=24` aligns to the next 32-byte boundary only if this can be done by skipping 23 bytes or less, `-falign-functions=32:7` aligns to the next 32-byte boundary only if this can be done by skipping 6 bytes or less.

The second pair of *n2*:*m2* values allows you to specify a secondary alignment: `-falign-functions=64:7:32:3` aligns to the next 64-byte boundary if this can be done by skipping 6 bytes or less, otherwise aligns to the next 32-byte boundary if this can be done by skipping 2 bytes or less. If *m2* is not specified, it defaults to *n2*.

Some assemblers only support this flag when *n* is a power of two; in that case, it is rounded up.

`-fno-align-functions` and `-falign-functions=1` are equivalent and mean that functions are not aligned.

If *n* is not specified or is zero, use a machine-dependent default. The maximum allowed *n* option value is 65536.

Enabled at levels `-O2`, `-O3`.

`-flimit-function-alignment`
: If this option is enabled, the compiler tries to avoid unnecessarily overaligning functions. It attempts to instruct the assembler to align by the amount specified by `-falign-functions`, but not to skip more bytes than the size of the function.

`-falign-labels`
`-falign-labels=n`
`-falign-labels=n:m`
`-falign-labels=n:m:n2`
`-falign-labels=n:m:n2:m2`
: Align all branch targets to a power-of-two boundary.

Parameters of this option are analogous to the `-falign-functions` option. `-fno-align-labels` and `-falign-labels=1` are equivalent and mean that labels are not aligned.

If `-falign-loops` or `-falign-jumps` are applicable and are greater than this value, then their values are used instead.

If *n* is not specified or is zero, use a machine-dependent default which is very likely to be '`1`', meaning no alignment. The maximum allowed *n* option value is 65536.

Enabled at levels `-O2`, `-O3`.

`-falign-loops`
`-falign-loops=n`
`-falign-loops=n:m`
`-falign-loops=n:m:n2`
`-falign-loops=n:m:n2:m2`
: Align loops to a power-of-two boundary. If the loops are executed many times, this makes up for any execution of the dummy padding instructions. This is an optimization of code performance and alignment is ignored for loops considered cold.

If `-falign-labels` is greater than this value, then its value is used instead.

Parameters of this option are analogous to the `-falign-functions` option. `-fno-align-loops` and `-falign-loops=1` are equivalent and mean that loops are not aligned. The maximum allowed *n* option value is 65536.

If *n* is not specified or is zero, use a machine-dependent default.

Enabled at levels `-O2`, `-O3`.

`-falign-jumps`
`-falign-jumps=`*n*
`-falign-jumps=`*n*:*m*
`-falign-jumps=`*n*:*m*:*n2*
`-falign-jumps=`*n*:*m*:*n2*:*m2*

Align branch targets to a power-of-two boundary, for branch targets where the targets can only be reached by jumping. In this case, no dummy operations need be executed. This is an optimization of code performance and alignment is ignored for jumps considered cold.

If `-falign-labels` is greater than this value, then its value is used instead.

Parameters of this option are analogous to the `-falign-functions` option. `-fno-align-jumps` and `-falign-jumps=1` are equivalent and mean that loops are not aligned.

If *n* is not specified or is zero, use a machine-dependent default. The maximum allowed *n* option value is 65536.

Enabled at levels `-O2`, `-O3`.

`-fmin-function-alignment`

Specify minimal alignment of functions to the next power-of-two greater than or equal to *n*. Unlike `-falign-functions` this alignment is applied also to all functions (even those considered cold). The alignment is also not affected by `-flimit-function-alignment`

`-fno-allocation-dce`

Do not remove unused C++ allocations (using operator `new` and operator `delete`) in dead code elimination.

See also `-fmalloc-dce`.

`-fallow-store-data-races`

Allow the compiler to perform optimizations that may introduce new data races on stores, without proving that the variable cannot be concurrently accessed by other threads. Does not affect optimization of local data. It is safe to use this option if it is known that global data will not be accessed by multiple threads.

Examples of optimizations enabled by `-fallow-store-data-races` include hoisting or if-conversions that may cause a value that was already in memory to be re-written with that same value. Such re-writing is safe in a single threaded context but may be unsafe in a multi-threaded context. Note that on some processors, if-conversions may be required in order to enable vectorization.

Enabled at level `-Ofast`.

`-funit-at-a-time`

This option is left for compatibility reasons. `-funit-at-a-time` has no effect, while `-fno-unit-at-a-time` implies `-fno-toplevel-reorder` and `-fno-section-anchors`.

Enabled by default.

-fno-toplevel-reorder
: Do not reorder top-level functions, variables, and asm statements. Output them in the same order that they appear in the input file. When this option is used, unreferenced static variables are not removed. This option is intended to support existing code that relies on a particular ordering. For new code, it is better to use attributes when possible.

  -ftoplevel-reorder is the default at -O1 and higher, and also at -O0 if -fsection-anchors is explicitly requested. Additionally -fno-toplevel-reorder implies -fno-section-anchors.

-funreachable-traps
: With this option, the compiler turns calls to __builtin_unreachable into traps, instead of using them for optimization. This also affects any such calls implicitly generated by the compiler.

  This option has the same effect as -fsanitize=unreachable -fsanitize-trap=unreachable, but does not affect the values of those options. If -fsanitize=unreachable is enabled, that option takes priority over this one.

  This option is enabled by default at -O0 and -Og.

-fweb
: Constructs webs as commonly used for register allocation purposes and assign each web individual pseudo register. This allows the register allocation pass to operate on pseudos directly, but also strengthens several other optimization passes, such as CSE, loop optimizer and trivial dead code remover. It can, however, make debugging impossible, since variables no longer stay in a "home register".

  Enabled by default with -funroll-loops.

-fwhole-program
: Assume that the current compilation unit represents the whole program being compiled. All public functions and variables with the exception of main and those merged by attribute externally_visible become static functions and in effect are optimized more aggressively by interprocedural optimizers.

  With -flto this option has a limited use. In most cases the precise list of symbols used or exported from the binary is known the resolution info passed to the link-time optimizer by the linker plugin. It is still useful if no linker plugin is used or during incremental link step when final code is produced (with -flto -flinker-output=nolto-rel).

-flto[=*n*]
: This option runs the standard link-time optimizer. When invoked with source code, it generates GIMPLE (one of GCC's internal representations) and writes it to special ELF sections in the object file. When the object files are linked together, all the function bodies are read from these ELF sections and instantiated as if they had been part of the same translation unit.

  To use the link-time optimizer, -flto and optimization options should be specified at compile time and during the final link. It is recommended that you compile all the files participating in the same link with the same options and also specify those options at link time. For example:

```
gcc -c -O2 -flto foo.c
gcc -c -O2 -flto bar.c
gcc -o myprog -flto -O2 foo.o bar.o
```

The first two invocations to GCC save a bytecode representation of GIMPLE into special ELF sections inside `foo.o` and `bar.o`. The final invocation reads the GIMPLE bytecode from `foo.o` and `bar.o`, merges the two files into a single internal image, and compiles the result as usual. Since both `foo.o` and `bar.o` are merged into a single image, this causes all the interprocedural analyses and optimizations in GCC to work across the two files as if they were a single one. This means, for example, that the inliner is able to inline functions in `bar.o` into functions in `foo.o` and vice-versa.

Another (simpler) way to enable link-time optimization is:

```
gcc -o myprog -flto -O2 foo.c bar.c
```

The above generates bytecode for `foo.c` and `bar.c`, merges them together into a single GIMPLE representation and optimizes them as usual to produce `myprog`.

The important thing to keep in mind is that to enable link-time optimizations you need to use the GCC driver to perform the link step. GCC automatically performs link-time optimization if any of the objects involved were compiled with the `-flto` command-line option. You can always override the automatic decision to do link-time optimization by passing `-fno-lto` to the link command.

To make whole-program optimization effective, it is necessary to make certain assumptions. The compiler needs to know what functions and variables can be accessed by libraries and runtime outside of the link-time optimized unit. When supported by the linker, the linker plugin (see `-fuse-linker-plugin`) passes information to the compiler about used and externally visible symbols. When the linker plugin is not available, `-fwhole-program` should be used to allow the compiler to make these assumptions, which leads to more aggressive optimization decisions.

When a file is compiled with `-flto` without `-fuse-linker-plugin`, the generated object file is larger than a regular object file because it contains GIMPLE bytecodes and the usual final code (see `-ffat-lto-objects`). This means that object files with LTO information can be linked as normal object files; if `-fno-lto` is passed to the linker, no interprocedural optimizations are applied. Note that when `-fno-fat-lto-objects` is enabled the compile stage is faster but you cannot perform a regular, non-LTO link on them.

When producing the final binary, GCC only applies link-time optimizations to those files that contain bytecode. Therefore, you can mix and match object files and libraries with GIMPLE bytecodes and final object code. GCC automatically selects which files to optimize in LTO mode and which files to link without further processing.

Generally, options specified at link time override those specified at compile time, although in some cases GCC attempts to infer link-time options from the settings used to compile the input files.

If you do not specify an optimization level option `-O` at link time, then GCC uses the highest optimization level used when compiling the object files. Note that it is generally ineffective to specify an optimization level option only at link time and not at compile time, for two reasons. First, compiling without optimization suppresses compiler passes that gather information needed for effective optimization at link time. Second, some early optimization passes can be performed only at compile time and not at link time.

There are some code generation flags preserved by GCC when generating bytecodes, as they need to be used during the final link. Currently, the following options and their settings are taken from the first object file that explicitly specifies them: `-fcommon`, `-fexceptions`, `-fnon-call-exceptions`, `-fgnu-tm` and all the `-m` target flags.

The following options `-fPIC`, `-fpic`, `-fpie` and `-fPIE` are combined based on the following scheme:

```
-fPIC + -fpic = -fpic
-fPIC + -fno-pic = -fno-pic
-fpic/-fPIC + (no option) = (no option)
-fPIC + -fPIE = -fPIE
-fpic + -fPIE = -fpie
-fPIC/-fpic + -fpie = -fpie
```

Certain ABI-changing flags are required to match in all compilation units, and trying to override this at link time with a conflicting value is ignored. This includes options such as `-freg-struct-return` and `-fpcc-struct-return`.

Other options such as `-ffp-contract`, `-fno-strict-overflow`, `-fwrapv`, `-fno-trapv` or `-fno-strict-aliasing` are passed through to the link stage and merged conservatively for conflicting translation units. Specifically `-fno-strict-overflow`, `-fwrapv` and `-fno-trapv` take precedence; and for example `-ffp-contract=off` takes precedence over `-ffp-contract=fast`. You can override them at link time.

Diagnostic options such as `-Wstringop-overflow` are passed through to the link stage and their setting matches that of the compile-step at function granularity. Note that this matters only for diagnostics emitted during optimization. Note that code transforms such as inlining can lead to warnings being enabled or disabled for regions if code not consistent with the setting at compile time.

When you need to pass options to the assembler via `-Wa` or `-Xassembler` make sure to either compile such translation units with `-fno-lto` or consistently use the same assembler options on all translation units. You can alternatively also specify assembler options at LTO link time.

To enable debug info generation you need to supply `-g` at compile time. If any of the input files at link time were built with debug info generation enabled the link will enable debug info generation as well. Any elaborate debug info settings like the dwarf level `-gdwarf-5` need to be explicitly repeated at the linker command line and mixing different settings in different translation units is discouraged.

If LTO encounters objects with C linkage declared with incompatible types in separate translation units to be linked together (undefined behavior according to ISO C99 6.2.7), a non-fatal diagnostic may be issued. The behavior is still undefined at run time. Similar diagnostics may be raised for other languages.

Another feature of LTO is that it is possible to apply interprocedural optimizations on files written in different languages:

```
gcc -c -flto foo.c
g++ -c -flto bar.cc
gfortran -c -flto baz.f90
g++ -o myprog -flto -O3 foo.o bar.o baz.o -lgfortran
```

Notice that the final link is done with `g++` to get the C++ runtime libraries and `-lgfortran` is added to get the Fortran runtime libraries. In general, when mixing languages in LTO mode, you should use the same link command options as when mixing languages in a regular (non-LTO) compilation.

If object files containing GIMPLE bytecode are stored in a library archive, say `libfoo.a`, it is possible to extract and use them in an LTO link if you are using a linker with plugin support. To create static libraries suitable for LTO, use `gcc-ar` and `gcc-ranlib` instead of `ar` and `ranlib`; to show the symbols of object files with GIMPLE bytecode, use `gcc-nm`. Those commands require that `ar`, `ranlib` and `nm` have been compiled with plugin support. At link time, use the flag `-fuse-linker-plugin` to ensure that the library participates in the LTO optimization process:

```
gcc -o myprog -O2 -flto -fuse-linker-plugin a.o b.o -lfoo
```

With the linker plugin enabled, the linker extracts the needed GIMPLE files from `libfoo.a` and passes them on to the running GCC to make them part of the aggregated GIMPLE image to be optimized.

If you are not using a linker with plugin support and/or do not enable the linker plugin, then the objects inside `libfoo.a` are extracted and linked as usual, but they do not participate in the LTO optimization process. In order to make a static library suitable for both LTO optimization and usual linkage, compile its object files with `-flto -ffat-lto-objects`.

Link-time optimizations do not require the presence of the whole program to operate. If the program does not require any symbols to be exported, it is possible to combine `-flto` and `-fwhole-program` to allow the interprocedural optimizers to use more aggressive assumptions which may lead to improved optimization opportunities. Use of `-fwhole-program` is not needed when linker plugin is active (see `-fuse-linker-plugin`).

The current implementation of LTO makes no attempt to generate bytecode that is portable between different types of hosts. The bytecode files are versioned and there is a strict version check, so bytecode files generated in one version of GCC do not work with an older or newer version of GCC.

Link-time optimization does not work well with generation of debugging information on systems other than those using a combination of ELF and DWARF.

If you specify the optional *n*, the optimization and code generation done at link time is executed in parallel using *n* parallel jobs by utilizing an installed `make` program. The environment variable `MAKE` may be used to override the program used.

You can also specify `-flto=jobserver` to use GNU make's job server mode to determine the number of parallel jobs. This is useful when the Makefile calling GCC is already executing in parallel. You must prepend a '`+`' to the command recipe in the parent Makefile for this to work. This option likely only works if MAKE is GNU make. Even without the option value, GCC tries to automatically detect a running GNU make's job server.

Use -flto=auto to use GNU make's job server, if available, or otherwise fall back to autodetection of the number of CPU threads present in your system.

-flto-partition=*alg*
: Specify the partitioning algorithm used by the link-time optimizer. The value is either '1to1' to specify a partitioning mirroring the original source files or 'balanced' to specify partitioning into equally sized chunks (whenever possible) or 'max' to create new partition for every symbol where possible or 'cache' to balance chunk sizes while keeping related symbols together for better caching in incremental LTO. Specifying 'none' as an algorithm disables partitioning and streaming completely. The default value is 'balanced'. While '1to1' can be used as an workaround for various code ordering issues, the 'max' partitioning is intended for internal testing only. The value 'one' specifies that exactly one partition should be used while the value 'none' bypasses partitioning and executes the link-time optimization step directly from the WPA phase.

-flto-incremental=*path*
: Enable incremental LTO, with its cache in given existing directory. Can significantly shorten edit-compile cycles with LTO.

When used with LTO (-flto), the output of translation units inside LTO is cached. Cached translation units are likely to be encountered again when recompiling with small code changes, leading to recompile time reduction.

Multiple GCC instances can use the same cache in parallel.

-flto-incremental-cache-size=*n*
: Specifies number of cache entries in incremental LTO after which to prune old entries. This is a soft limit, temporarily there may be more entries.

-flto-compression-level=*n*
: This option specifies the level of compression used for intermediate language written to LTO object files, and is only meaningful in conjunction with LTO mode (-flto). GCC currently supports two LTO compression algorithms. For zstd, valid values are 0 (no compression) to 19 (maximum compression), while zlib supports values from 0 to 9. Values outside this range are clamped to either minimum or maximum of the supported values. If the option is not given, a default balanced compression setting is used.

-fuse-linker-plugin
: Enables the use of a linker plugin during link-time optimization. This option relies on plugin support in the linker, which is available in gold or in GNU ld 2.21 or newer.

This option enables the extraction of object files with GIMPLE bytecode out of library archives. This improves the quality of optimization by exposing more code to the link-time optimizer. This information specifies what symbols can be accessed externally (by non-LTO object or during dynamic linking). Resulting code quality improvements on binaries (and shared libraries that use hidden visibility) are similar to `-fwhole-program`. See `-flto` for a description of the effect of this flag and how to use it.

This option is enabled by default when LTO support in GCC is enabled and GCC was configured for use with a linker supporting plugins (GNU ld 2.21 or newer or gold).

`-ffat-lto-objects`

Fat LTO objects are object files that contain both the intermediate language and the object code. This makes them usable for both LTO linking and normal linking. This option is effective only when compiling with `-flto` and is ignored at link time.

`-fno-fat-lto-objects` improves compilation time over plain LTO, but requires the complete toolchain to be aware of LTO. It requires a linker with linker plugin support for basic functionality. Additionally, `nm`, `ar` and `ranlib` need to support linker plugins to allow a full-featured build environment (capable of building static libraries etc). GCC provides the `gcc-ar`, `gcc-nm`, `gcc-ranlib` wrappers to pass the right options to these tools. With non fat LTO makefiles need to be modified to use them.

Note that modern binutils provide plugin auto-load mechanism. Installing the linker plugin into `$libdir/bfd-plugins` has the same effect as usage of the command wrappers (`gcc-ar`, `gcc-nm` and `gcc-ranlib`).

The default is `-fno-fat-lto-objects` on targets with linker plugin support.

`-fcompare-elim`

After register allocation and post-register allocation instruction splitting, identify arithmetic instructions that compute processor flags similar to a comparison operation based on that arithmetic. If possible, eliminate the explicit comparison operation.

This pass only applies to certain targets that cannot explicitly represent the comparison operation before register allocation is complete.

Enabled at levels `-O1`, `-O2`, `-O3`, `-Os`.

`-ffold-mem-offsets`
`-fno-fold-mem-offsets`

Try to eliminate add instructions by folding them in memory loads/stores.

Enabled at levels `-O2`, `-O3`.

`-fcprop-registers`

After register allocation and post-register allocation instruction splitting, perform a copy-propagation pass to try to reduce scheduling dependencies and occasionally eliminate the copy.

Enabled at levels `-O1`, `-O2`, `-O3`, `-Os`.

`-fprofile-correction`

Profiles collected using an instrumented binary for multi-threaded programs may be inconsistent due to missed counter updates. When this option is specified, GCC uses heuristics to correct or smooth out such inconsistencies. By default, GCC emits an error message when an inconsistent profile is detected.

This option is enabled by `-fauto-profile`.

`-fprofile-partial-training`

With `-fprofile-use` all portions of programs not executed during training runs are optimized aggressively for size rather than speed. In some cases it is not practical to train all possible hot paths in the program. (For example, it may contain functions specific to a given hardware and training may not cover all hardware configurations the program later runs on.) With `-fprofile-partial-training` profile feedback is ignored for all functions not executed during the training runs, causing them to be optimized as if they were compiled without profile feedback. This leads to better performance when the training is not representative at the cost of significantly bigger code.

`-fprofile-use`
`-fprofile-use=`*path*

Enable profile feedback-directed optimizations, and the following optimizations, many of which are generally profitable only with profile feedback available:

```
-fbranch-probabilities  -fprofile-values
-funroll-loops  -fpeel-loops  -ftracer  -fvpt
-finline-functions  -fipa-cp  -fipa-cp-clone  -fipa-bit-cp
-fpredictive-commoning  -fsplit-loops  -funswitch-loops
-fgcse-after-reload  -ftree-loop-vectorize  -ftree-slp-vectorize
-fvect-cost-model=dynamic  -ftree-loop-distribute-patterns
-fprofile-reorder-functions
```

Before you can use this option, you must first generate profiling information. See Section 3.13 [Instrumentation Options], page 275, for information about the `-fprofile-generate` option.

By default, GCC emits an error message if the feedback profiles do not match the source code. This error can be turned into a warning by using `-Wno-error=coverage-mismatch`. Note this may result in poorly optimized code. Additionally, by default, GCC also emits a warning message if the feedback profiles do not exist (see `-Wmissing-profile`).

If *path* is specified, GCC looks at the *path* to find the profile feedback data files. See `-fprofile-dir`.

`-fauto-profile`
`-fauto-profile=`*path*

Enable sampling-based feedback-directed optimizations, and the following optimizations, many of which are generally profitable only with profile feedback available:

```
-fbranch-probabilities  -fprofile-values
-funroll-loops  -fpeel-loops  -ftracer  -fvpt
-finline-functions  -fipa-cp  -fipa-cp-clone  -fipa-bit-cp
-fpredictive-commoning  -fsplit-loops  -funswitch-loops
-fgcse-after-reload  -ftree-loop-vectorize  -ftree-slp-vectorize
-fvect-cost-model=dynamic  -ftree-loop-distribute-patterns
-fprofile-correction
```

path is the name of a file containing AutoFDO profile information. If omitted, it defaults to `fbdata.afdo` in the current directory.

Producing an AutoFDO profile data file requires running your program with the `perf` utility on a supported GNU/Linux target system. For more information, see `https://perfwiki.github.io/main/`.

E.g.

```
perf record -e br_inst_retired:near_taken -b -o perf.data \
    -- your_program
```

Then use the `create_gcov` tool to convert the raw profile data to a format that can be used by GCC. You must also supply the unstripped binary for your program to this tool. See `https://github.com/google/autofdo`.

E.g.

```
create_gcov --binary=your_program.unstripped --profile=perf.data \
    --gcov=profile.afdo
```

`-fauto-profile-inlining`

When auto-profile is available inline all relevant functions which was inlined in the tran run before reading the profile feedback. This improves context sensitivity of the profile. Enabled by default.

The following options control compiler behavior regarding floating-point arithmetic. These options trade off between speed and correctness. All must be specifically enabled.

`-fexcess-precision=`*style*

This option allows control over excess precision on machines where floating-point operations occur in a format with more precision or range than the IEEE standard and interchange floating-point types. An example of such a target is x87 floating point on x86 processors, which uses an 80-bit representation internally instead of the 64-bit IEEE format. For most programs, the excess precision is harmless, but some programs may rely on the requirements of the C or C++ language standards for handling IEEE values.

By default, `-fexcess-precision=fast` is in effect; this means that operations may be carried out in a wider precision than the types specified in the source if that would result in faster code, and it is unpredictable when rounding to the types specified in the source code takes place. When compiling C or C++, if `-fexcess-precision=standard` is specified then excess precision follows the rules specified in ISO C99 or C++; in particular, both casts and assignments cause values to be rounded to their semantic types (whereas `-ffloat-store` only affects assignments). This option is enabled by default for C or C++ if a strict conformance option such as `-std=c99` or `-std=c++17` is used. `-ffast-math` enables `-fexcess-precision=fast` by default regardless of whether a strict conformance option is used. If `-fexcess-precision=16` is specified, constants and the results of expressions with types `_Float16` and `__bf16` are computed without excess precision.

`-fexcess-precision=standard` is not implemented for languages other than C or C++. On the x86, it has no effect if `-mfpmath=sse` or `-mfpmath=sse+387` is specified; in the former case, IEEE semantics apply without excess precision, and in the latter, rounding is unpredictable.

`-ffloat-store`
: Do not store floating-point variables in registers, and inhibit other options that might change whether a floating-point value is taken from a register or memory. This option has generally been subsumed by `-fexcess-precision=standard`, which is more general. If you do use `-ffloat-store`, you may need to modify your program to explicitly store intermediate computations in temporary variables since `-ffloat-store` handles rounding to IEEE format only on assignments and not casts as `-fexcess-precision=standard` does.

`-ffast-math`
: Sets the options `-fno-math-errno`, `-funsafe-math-optimizations`, `-ffinite-math-only`, `-fno-rounding-math`, `-fno-signaling-nans`, `-fcx-limited-range` and `-fexcess-precision=fast`.

  This option causes the preprocessor macro `__FAST_MATH__` to be defined.

  This option is not turned on by any `-O` option besides `-Ofast` since it can result in incorrect output for programs that depend on an exact implementation of IEEE or ISO rules/specifications for math functions. It may, however, yield faster code for programs that do not require the guarantees of these specifications.

`-fno-math-errno`
: Do not set `errno` after calling math functions that are executed with a single instruction, e.g., `sqrt`. A program that relies on IEEE exceptions for math error handling may want to use this flag for speed while maintaining IEEE arithmetic compatibility.

  This option is not turned on by any `-O` option besides `-Ofast` since it can result in incorrect output for programs that depend on an exact implementation of IEEE or ISO rules/specifications for math functions. It may, however, yield faster code for programs that do not require the guarantees of these specifications.

  The default is `-fmath-errno`.

  On Darwin systems, the math library never sets `errno`. There is therefore no reason for the compiler to consider the possibility that it might, and `-fno-math-errno` is the default.

`-funsafe-math-optimizations`
: Allow optimizations for floating-point arithmetic that (a) assume that arguments and results are valid and (b) may violate IEEE or ANSI standards. When used at link time, it may include libraries or startup files that change the default FPU control word or other similar optimizations.

  This option is not turned on by any `-O` option besides `-Ofast` since it can result in incorrect output for programs that depend on an exact implementation of IEEE or ISO rules/specifications for math functions. It may, however, yield faster code for programs that do not require the guarantees of these specifications. Enables `-fno-signed-zeros`, `-fno-trapping-math`, `-fassociative-math` and `-freciprocal-math`.

  The default is `-fno-unsafe-math-optimizations`.

`-fassociative-math`

Allow re-association of operands in series of floating-point operations. This violates the ISO C and C++ language standard by possibly changing computation result. NOTE: re-ordering may change the sign of zero as well as ignore NaNs and inhibit or create underflow or overflow (and thus cannot be used on code that relies on rounding behavior like `(x + 2**52) - 2**52`. May also reorder floating-point comparisons and thus may not be used when ordered comparisons are required. This option requires that both `-fno-signed-zeros` and `-fno-trapping-math` be in effect. Moreover, it doesn't make much sense with `-frounding-math`. For Fortran the option is automatically enabled when both `-fno-signed-zeros` and `-fno-trapping-math` are in effect.

The default is `-fno-associative-math`.

`-freciprocal-math`

Allow the reciprocal of a value to be used instead of dividing by the value if this enables optimizations. For example `x / y` can be replaced with `x * (1/y)`, which is useful if `(1/y)` is subject to common subexpression elimination. Note that this loses precision and increases the number of flops operating on the value.

The default is `-fno-reciprocal-math`.

`-ffinite-math-only`

Allow optimizations for floating-point arithmetic that assume that arguments and results are not NaNs or +-Infs.

This option is not turned on by any `-O` option besides `-Ofast` since it can result in incorrect output for programs that depend on an exact implementation of IEEE or ISO rules/specifications for math functions. It may, however, yield faster code for programs that do not require the guarantees of these specifications.

The default is `-fno-finite-math-only`.

`-fno-signed-zeros`

Allow optimizations for floating-point arithmetic that ignore the signedness of zero. IEEE arithmetic specifies the behavior of distinct +0.0 and −0.0 values, which then prohibits simplification of expressions such as x+0.0 or 0.0*x (even with `-ffinite-math-only`). This option implies that the sign of a zero result isn't significant.

The default is `-fsigned-zeros`.

`-fno-trapping-math`

Compile code assuming that floating-point operations cannot generate user-visible traps. These traps include division by zero, overflow, underflow, inexact result and invalid operation. This option requires that `-fno-signaling-nans` be in effect. Setting this option may allow faster code if one relies on "non-stop" IEEE arithmetic, for example.

This option is not turned on by any `-O` option besides `-Ofast` since it can result in incorrect output for programs that depend on an exact implementation of IEEE or ISO rules/specifications for math functions.

The default is `-ftrapping-math`.

Future versions of GCC may provide finer control of this setting using C99's `FENV_ACCESS` pragma. This command-line option will be used along with `-frounding-math` to specify the default state for `FENV_ACCESS`.

`-frounding-math`
: Disable transformations and optimizations that assume default floating-point rounding behavior (round-to-nearest). This option should be specified for programs that change the FP rounding mode dynamically, or that may be executed with a non-default rounding mode. This option disables constant folding of floating-point expressions at compile time (which may be affected by rounding mode) and arithmetic transformations that are unsafe in the presence of sign-dependent rounding modes.

The default is `-fno-rounding-math`.

This option is experimental and does not currently guarantee to disable all GCC optimizations that are affected by rounding mode. Future versions of GCC may provide finer control of this setting using C99's `FENV_ACCESS` pragma. This command-line option will be used along with `-ftrapping-math` to specify the default state for `FENV_ACCESS`.

`-fsignaling-nans`
: Compile code assuming that IEEE signaling NaNs may generate user-visible traps during floating-point operations. Setting this option disables optimizations that may change the number of exceptions visible with signaling NaNs. This option implies `-ftrapping-math`.

This option causes the preprocessor macro `__SUPPORT_SNAN__` to be defined.

The default is `-fno-signaling-nans`.

This option is experimental and does not currently guarantee to disable all GCC optimizations that affect signaling NaN behavior.

`-fsingle-precision-constant`
: Treat floating-point constants as single precision instead of implicitly converting them to double-precision constants.

`-fcx-limited-range`
: When enabled, this option states that a range reduction step is not needed when performing complex division. Also, there is no checking whether the result of a complex multiplication or division is `NaN + I*NaN`, with an attempt to rescue the situation in that case. The option is enabled by `-ffast-math`.

This option controls the default setting of the ISO C99 `CX_LIMITED_RANGE` pragma. Nevertheless, the option applies to all languages.

`-fcx-fortran-rules`
: Complex multiplication and division follow Fortran rules. Range reduction is done as part of complex division, but there is no checking whether the result of a complex multiplication or division is `NaN + I*NaN`, with an attempt to rescue the situation in that case.

`-fcx-method=method`

Complex multiplication and division follow the stated *method*. The *method* argument should be one of '`limited-range`', '`fortran`' or '`stdc`'.

The default is to honor language specific constraints which means '`fortran`' for Fortran and '`stdc`' otherwise.

The following options control optimizations that may improve performance, but are not enabled by any `-O` options. This section includes experimental options that may produce broken code.

`-fbranch-probabilities`

After running a program compiled with `-fprofile-arcs` (see Section 3.13 [Instrumentation Options], page 275), you can compile it a second time using `-fbranch-probabilities`, to improve optimizations based on the number of times each branch was taken. When a program compiled with `-fprofile-arcs` exits, it saves arc execution counts to a file called `sourcename.gcda` for each source file. The information in this data file is very dependent on the structure of the generated code, so you must use the same source code and the same optimization options for both compilations. See details about the file naming in `-fprofile-arcs`.

With `-fbranch-probabilities`, GCC puts a '`REG_BR_PROB`' note on each '`JUMP_INSN`' and '`CALL_INSN`'. These can be used to improve optimization. Currently, they are only used in one place: in `reorg.cc`, instead of guessing which path a branch is most likely to take, the '`REG_BR_PROB`' values are used to exactly determine which path is taken more often.

Enabled by `-fprofile-use` and `-fauto-profile`.

`-fprofile-values`

If combined with `-fprofile-arcs`, it adds code so that some data about values of expressions in the program is gathered.

With `-fbranch-probabilities`, it reads back the data gathered from profiling values of expressions for usage in optimizations.

Enabled by `-fprofile-generate`, `-fprofile-use`, and `-fauto-profile`.

`-fprofile-reorder-functions`

Function reordering based on profile instrumentation collects first time of execution of a function and orders these functions in ascending order, aiming to optimize program startup through more efficient loading of text segments.

Enabled with `-fprofile-use`.

`-fvpt`

If combined with `-fprofile-arcs`, this option instructs the compiler to add code to gather information about values of expressions.

With `-fbranch-probabilities`, it reads back the data gathered and actually performs the optimizations based on them. Currently the optimizations include specialization of division operations using the knowledge about the value of the denominator.

Enabled with `-fprofile-use` and `-fauto-profile`.

`-frename-registers`
: Attempt to avoid false dependencies in scheduled code by making use of registers left over after register allocation. This optimization most benefits processors with lots of registers. Depending on the debug information format adopted by the target, however, it can make debugging impossible, since variables no longer stay in a "home register".

  Enabled by default with `-funroll-loops`.

`-fschedule-fusion`
: Performs a target dependent pass over the instruction stream to schedule instructions of same type together because target machine can execute them more efficiently if they are adjacent to each other in the instruction flow.

  Enabled at levels `-O2`, `-O3`, `-Os`.

`-fdep-fusion`
: Detect macro-op fusible pairs consisting of single-use instructions and their uses, and place such pairs together in the instruction stream to increase fusion opportunities in hardware. This pass is executed once before register allocation, and another time before register renaming.

  Enabled at levels `-O2`, `-O3`, `-Os`.

`-ftracer`
: Perform tail duplication to enlarge superblock size. This transformation simplifies the control flow of the function allowing other optimizations to do a better job.

  Enabled by `-fprofile-use` and `-fauto-profile`.

`-funroll-loops`
: Unroll loops whose number of iterations can be determined at compile time or upon entry to the loop. `-funroll-loops` implies `-frerun-cse-after-loop`, `-fweb` and `-frename-registers`. It also turns on complete loop peeling (i.e. complete removal of loops with a small constant number of iterations). This option makes code larger, and may or may not make it run faster.

  Enabled by `-fprofile-use` and `-fauto-profile`.

`-funroll-all-loops`
: Unroll all loops, even if their number of iterations is uncertain when the loop is entered. This usually makes programs run more slowly. `-funroll-all-loops` implies the same options as `-funroll-loops`.

`-fpeel-loops`
: Peels loops for which there is enough information that they do not roll much (from profile feedback or static analysis). It also turns on complete loop peeling (i.e. complete removal of loops with small constant number of iterations).

  Enabled by `-O3`, `-fprofile-use`, and `-fauto-profile`.

`-fmalloc-dce`
: Control whether `malloc` (and its variants such as `calloc` or `strdup`), can be optimized away provided its return value is only used as a parameter of `free` call or compared with `NULL`. If `-fmalloc-dce=1` is used, only calls to `free` are

allowed while with `-fmalloc-dce=2` also comparisons with `NULL` pointer are considered safe to remove.

The default is `-fmalloc-dce=2`. See also `-fallocation-dce`.

`-fmove-loop-invariants`
: Enables the loop invariant motion pass in the RTL loop optimizer. Enabled at level `-O1` and higher, except for `-Og`.

`-fmove-loop-stores`
: Enables the loop store motion pass in the GIMPLE loop optimizer. This moves invariant stores to after the end of the loop in exchange for carrying the stored value in a register across the iteration. Note for this option to have an effect `-ftree-loop-im` has to be enabled as well. Enabled at level `-O1` and higher, except for `-Og`.

`-fsplit-loops`
: Split a loop into two if it contains a condition that's always true for one side of the iteration space and false for the other.

Enabled by `-fprofile-use` and `-fauto-profile`.

`-funswitch-loops`
: Move branches with loop invariant conditions out of the loop, with duplicates of the loop on both branches (modified according to result of the condition).

Enabled by `-fprofile-use` and `-fauto-profile`.

`-fversion-loops-for-strides`
: If a loop iterates over an array with a variable stride, create another version of the loop that assumes the stride is always one. For example:

```
for (int i = 0; i < n; ++i)
  x[i * stride] = ...;
```

becomes:

```
if (stride == 1)
  for (int i = 0; i < n; ++i)
    x[i] = ...;
else
  for (int i = 0; i < n; ++i)
    x[i * stride] = ...;
```

This is particularly useful for assumed-shape arrays in Fortran where (for example) it allows better vectorization assuming contiguous accesses. This flag is enabled by default at `-O3`. It is also enabled by `-fprofile-use` and `-fauto-profile`.

`-ffunction-sections`
`-fdata-sections`
: Place each function or data item into its own section in the output file if the target supports arbitrary sections. The name of the function or the name of the data item determines the section's name in the output file.

Use these options on systems where the linker can perform optimizations to improve locality of reference in the instruction space. Most systems using the ELF object format have linkers with such optimizations. On AIX, the linker rearranges sections (CSECTs) based on the call graph. The performance impact varies.

Together with a linker garbage collection (linker `--gc-sections` option) these options may lead to smaller statically-linked executables (after stripping).

On ELF/DWARF systems these options do not degenerate the quality of the debug information. There could be issues with other object files/debug info formats.

Only use these options when there are significant benefits from doing so. When you specify these options, the assembler and linker create larger object and executable files and are also slower. These options affect code generation. They prevent optimizations by the compiler and assembler using relative locations inside a translation unit since the locations are unknown until link time. An example of such an optimization is relaxing calls to short call instructions.

`-fstdarg-opt`
: Optimize the prologue of variadic argument functions with respect to usage of those arguments.

`-fsection-anchors`
: Try to reduce the number of symbolic address calculations by using shared "anchor" symbols to address nearby objects. This transformation can help to reduce the number of GOT entries and GOT accesses on some targets.

For example, the implementation of the following function `foo`:

```
static int a, b, c;
int foo (void) { return a + b + c; }
```

usually calculates the addresses of all three variables, but if you compile it with `-fsection-anchors`, it accesses the variables from a common anchor point instead. The effect is similar to the following pseudocode (which isn't valid C):

```
int foo (void)
{
  register int *xr = &x;
  return xr[&a - &x] + xr[&b - &x] + xr[&c - &x];
}
```

Not all targets support this option.

`-fzero-call-used-regs=`*`choice`*
: Zero call-used registers at function return to increase program security by either mitigating Return-Oriented Programming (ROP) attacks or preventing information leakage through registers.

The possible values of *choice* are the same as for the `zero_call_used_regs` attribute (see Section 6.4.1 [Function Attributes], page 621). The default is '`skip`'.

You can control this behavior for a specific function by using the function attribute `zero_call_used_regs` (see Section 6.4.1 [Function Attributes], page 621).

`--param name=value`
`--param=name=value`

In some places, GCC uses various constants to control the amount of optimization that is done. For example, GCC does not inline functions that contain more than a certain number of instructions. You can control some of these constants on the command line using the `--param` option.

The names of specific parameters, and the meaning of the values, are tied to the internals of the compiler, and are subject to change without notice in future releases.

In order to get the minimal, maximal and default values of a parameter, use the `--help=param -Q` options.

In each case, the *value* is an integer. The following choices of *name* are recognized for all targets:

`auto-profile-bbs`
: If non-zero and used together with `-fauto-profile`, the auto-profile will be used to determine basic block profile. If zero, then only function level profile will be read.

`phiopt-factor-max-stmts-live`
: When factoring statements out of if/then/else, this is the max # of statements after the defining statement to be allow to extend the lifetime of a name

`predictable-branch-outcome`
: When branch is predicted to be taken with probability lower than this threshold (in percent), then it is considered well predictable.

`max-rtl-if-conversion-insns`
: RTL if-conversion tries to remove conditional branches around a block and replace them with conditionally executed instructions. This parameter gives the maximum number of instructions in a block which should be considered for if-conversion. The compiler will also use other heuristics to decide whether if-conversion is likely to be profitable.

`file-cache-files`
: Max number of files in the file cache. The file cache is used to print source lines in diagnostics and do some source checks like `-Wmisleading-indentation`.

`file-cache-lines`
: Max number of lines to index into file cache. When 0 this is automatically sized. The file cache is used to print source lines in diagnostics and do some source checks like `-Wmisleading-indentation`.

`max-rtl-if-conversion-predictable-cost`
: RTL if-conversion will try to remove conditional branches around a block and replace them with conditionally executed instructions.

These parameters give the maximum permissible cost for the sequence that would be generated by if-conversion depending on whether the branch is statically determined to be predictable or not. The units for this parameter are the same as those for the GCC internal seq_cost metric. The compiler will try to provide a reasonable default for this parameter using the BRANCH_COST target macro.

`max-crossjump-edges`
: The maximum number of incoming edges to consider for cross-jumping. The algorithm used by `-fcrossjumping` is $O(N^2)$ in the number of edges incoming to each block. Increasing values mean more aggressive optimization, making the compilation time increase with probably small improvement in executable size.

`min-crossjump-insns`
: The minimum number of instructions that must be matched at the end of two blocks before cross-jumping is performed on them. This value is ignored in the case where all instructions in the block being cross-jumped from are matched.

`max-grow-copy-bb-insns`
: The maximum code size expansion factor when copying basic blocks instead of jumping. The expansion is relative to a jump instruction.

`max-goto-duplication-insns`
: The maximum number of instructions to duplicate to a block that jumps to a computed goto. To avoid $O(N^2)$ behavior in a number of passes, GCC factors computed gotos early in the compilation process, and unfactors them as late as possible. Only computed jumps at the end of a basic blocks with no more than max-goto-duplication-insns are unfactored.

`max-delay-slot-insn-search`
: The maximum number of instructions to consider when looking for an instruction to fill a delay slot. If more than this arbitrary number of instructions are searched, the time savings from filling the delay slot are minimal, so stop searching. Increasing values mean more aggressive optimization, making the compilation time increase with probably small improvement in execution time.

`max-delay-slot-live-search`
: When trying to fill delay slots, the maximum number of instructions to consider when searching for a block with valid live register information. Increasing this arbitrarily chosen value means more aggressive optimization, increasing the compilation time. This parameter should be removed when the delay slot code is rewritten to maintain the control-flow graph.

`max-devirt-targets`
: This limits number of function a virtual call may be speculatively devirtualized to using static analysis (without profile feedback).

`max-gcse-memory`
: The approximate maximum amount of memory in `kB` that can be allocated in order to perform the global common subexpression elimination optimization. If more memory than specified is required, the optimization is not done.

`max-gcse-insertion-ratio`
: If the ratio of expression insertions to deletions is larger than this value for any expression, then RTL PRE inserts or removes the expression and thus leaves partially redundant computations in the instruction stream.

`max-pending-list-length`
: The maximum number of pending dependencies scheduling allows before flushing the current state and starting over. Large functions with few branches or calls can create excessively large lists which needlessly consume memory and resources.

`max-modulo-backtrack-attempts`
: The maximum number of backtrack attempts the scheduler should make when modulo scheduling a loop. Larger values can exponentially increase compilation time.

`max-inline-functions-called-once-loop-depth`
: Maximal loop depth of a call considered by inline heuristics that tries to inline all functions called once.

`max-inline-functions-called-once-insns`
: Maximal estimated size of functions produced while inlining functions called once.

`max-inline-insns-single`
: Several parameters control the tree inliner used in GCC. This number sets the maximum number of instructions (counted in GCC's internal representation) in a single function that the tree inliner considers for inlining. This only affects functions declared inline and methods implemented in a class declaration (C++).

`max-inline-insns-auto`
: When you use `-finline-functions` (included in `-O3`), a lot of functions that would otherwise not be considered for inlining by the compiler are investigated. To those functions, a different (more restrictive) limit compared to functions declared inline can be applied (`--param max-inline-insns-auto`).

`max-inline-insns-small`
: This is the bound applied to calls that are considered relevant with `-finline-small-functions`.

`max-inline-insns-size`
: This is the bound applied to calls that are optimized for size. Small growth may be desirable to anticipate optimization opportunities exposed by inlining.

`uninlined-function-insns`
: Number of instructions accounted by inliner for function overhead such as function prologue and epilogue.

`uninlined-function-time`
: Extra time accounted by inliner for function overhead such as time needed to execute function prologue and epilogue.

`inline-heuristics-hint-percent`
: The scale (in percents) applied to `inline-insns-single`, `inline-insns-single-O2`, `inline-insns-auto` when inline heuristics hints that inlining is very profitable (will enable later optimizations).

`uninlined-thunk-insns`
`uninlined-thunk-time`
: Same as `--param uninlined-function-insns` and `--param uninlined-function-time` but applied to function thunks.

`inline-min-speedup`
: When estimated performance improvement of caller + callee runtime exceeds this threshold (in percent), the function can be inlined regardless of the limit on `--param max-inline-insns-single` and `--param max-inline-insns-auto`.

`large-function-insns`
: The limit specifying really large functions. For functions larger than this limit after inlining, inlining is constrained by `--param large-function-growth`. This parameter is useful primarily to avoid extreme compilation time caused by non-linear algorithms used by the back end.

`large-function-growth`
: Specifies maximal growth of large functions caused by inlining in percents. For example, parameter value 100 limits large function growth to 2.0 times the original size.

`large-unit-insns`
: The limit specifying large translation unit. Growth caused by inlining of units larger than this limit is limited by `--param inline-unit-growth`. For small units this might be too tight. For example, consider a unit consisting of function A that is inline and B that just calls A three times. If B is small relative to A, the growth of unit is 300\% and yet such inlining is very sane. For very large units consisting of small inlineable functions, however, the overall unit growth limit is needed to avoid exponential explosion of code

size. Thus for smaller units, the size is increased to `--param large-unit-insns` before applying `--param inline-unit-growth`.

`lazy-modules`
: Maximum number of concurrently open C++ module files when lazy loading.

`inline-unit-growth`
: Specifies maximal overall growth of the compilation unit caused by inlining. For example, parameter value 20 limits unit growth to 1.2 times the original size. Cold functions (either marked cold via an attribute or by profile feedback) are not accounted into the unit size.

`ipa-cp-unit-growth`
: Specifies maximal overall growth of the compilation unit caused by interprocedural constant propagation. For example, parameter value 10 limits unit growth to 1.1 times the original size.

`ipa-cp-large-unit-insns`
: The size of translation unit that IPA-CP pass considers large.

`large-stack-frame`
: The limit specifying large stack frames. While inlining the algorithm is trying to not grow past this limit too much.

`large-stack-frame-growth`
: Specifies maximal growth of large stack frames caused by inlining in percents. For example, parameter value 1000 limits large stack frame growth to 11 times the original size.

`max-inline-insns-recursive`
`max-inline-insns-recursive-auto`
: Specifies the maximum number of instructions an out-of-line copy of a self-recursive inline function can grow into by performing recursive inlining.

  `--param max-inline-insns-recursive` applies to functions declared inline. For functions not declared inline, recursive inlining happens only when `-finline-functions` (included in `-O3`) is enabled; `--param max-inline-insns-recursive-auto` applies instead.

`max-inline-recursive-depth`
`max-inline-recursive-depth-auto`
: Specifies the maximum recursion depth used for recursive inlining.

  `--param max-inline-recursive-depth` applies to functions declared inline. For functions not declared inline, recursive inlining happens only when `-finline-functions` (included in `-O3`) is enabled; `--param max-inline-recursive-depth-auto` applies instead.

`min-inline-recursive-probability`
: Recursive inlining is profitable only for function having deep recursion in average and can hurt for function having little recursion depth by increasing the prologue size or complexity of function body to other optimizers.

  When profile feedback is available (see `-fprofile-generate`) the actual recursion depth can be guessed from the probability that function recurses via a given call expression. This parameter limits inlining only to call expressions whose probability exceeds the given threshold (in percents).

`early-inlining-insns`
: Specify growth that the early inliner can make. In effect it increases the amount of inlining for code having a large abstraction penalty.

`max-early-inliner-iterations`
: Limit of iterations of the early inliner. This basically bounds the number of nested indirect calls the early inliner can resolve. Deeper chains are still handled by late inlining.

`comdat-sharing-probability`
: Probability (in percent) that C++ inline function with comdat visibility are shared across multiple compilation units.

`modref-max-bases`
`modref-max-refs`
`modref-max-accesses`
: Specifies the maximal number of base pointers, references and accesses stored for a single function by mod/ref analysis.

`modref-max-tests`
: Specifies the maxmal number of tests alias oracle can perform to disambiguate memory locations using the mod/ref information. This parameter ought to be bigger than `--param modref-max-bases` and `--param modref-max-refs`.

`modref-max-depth`
: Specifies the maximum depth of DFS walk used by modref escape analysis. Setting to 0 disables the analysis completely.

`modref-max-escape-points`
: Specifies the maximum number of escape points tracked by modref per SSA-name.

`modref-max-adjustments`
: Specifies the maximum number the access range is enlarged during modref dataflow analysis.

`profile-func-internal-id`
: A parameter to control whether to use function internal id in profile database lookup. If the value is 0, the compiler uses an id that is based on function assembler name and filename, which makes

old profile data more tolerant to source changes such as function reordering etc.

`min-vect-loop-bound`
: The minimum number of iterations under which loops are not vectorized when `-ftree-vectorize` is used. The number of iterations after vectorization needs to be greater than the value specified by this option to allow vectorization.

`gcse-cost-distance-ratio`
: Scaling factor in calculation of maximum distance an expression can be moved by GCSE optimizations. This is currently supported only in the code hoisting pass. The bigger the ratio, the more aggressive code hoisting is with simple expressions, i.e., the expressions that have cost less than `gcse-unrestricted-cost`. Specifying 0 disables hoisting of simple expressions.

`gcse-unrestricted-cost`
: Cost, roughly measured as the cost of a single typical machine instruction, at which GCSE optimizations do not constrain the distance an expression can travel. This is currently supported only in the code hoisting pass. The lesser the cost, the more aggressive code hoisting is. Specifying 0 allows all expressions to travel unrestricted distances.

`max-hoist-depth`
: The depth of search in the dominator tree for expressions to hoist. This is used to avoid quadratic behavior in hoisting algorithm. The value of 0 does not limit on the search, but may slow down compilation of huge functions.

`max-tail-merge-comparisons`
: The maximum amount of similar bbs to compare a bb with. This is used to avoid quadratic behavior in tree tail merging.

`max-tail-merge-iterations`
: The maximum amount of iterations of the pass over the function. This is used to limit compilation time in tree tail merging.

`store-merging-allow-unaligned`
: Allow the store merging pass to introduce unaligned stores if it is legal to do so.

`max-stores-to-merge`
: The maximum number of stores to attempt to merge into wider stores in the store merging pass.

`max-store-chains-to-track`
: The maximum number of store chains to track at the same time in the attempt to merge them into wider stores in the store merging pass.

`max-stores-to-track`
: The maximum number of stores to track at the same time in the attemt to to merge them into wider stores in the store merging pass.

`max-unrolled-insns`
: The maximum number of instructions that a loop may have to be unrolled. If a loop is unrolled, this parameter also determines how many times the loop code is unrolled.

`max-average-unrolled-insns`
: The maximum number of instructions biased by probabilities of their execution that a loop may have to be unrolled. If a loop is unrolled, this parameter also determines how many times the loop code is unrolled.

`max-unroll-times`
: The maximum number of unrollings of a single loop.

`max-peeled-insns`
: The maximum number of instructions that a loop may have to be peeled. If a loop is peeled, this parameter also determines how many times the loop code is peeled.

`max-peel-times`
: The maximum number of peelings of a single loop.

`max-peel-branches`
: The maximum number of branches on the hot path through the peeled sequence.

`max-completely-peeled-insns`
: The maximum number of insns of a completely peeled loop.

`max-completely-peel-times`
: The maximum number of iterations of a loop to be suitable for complete peeling.

`max-completely-peel-loop-nest-depth`
: The maximum depth of a loop nest suitable for complete peeling.

`max-unswitch-insns`
: The maximum number of insns of an unswitched loop.

`max-unswitch-depth`
: The maximum depth of a loop nest to be unswitched.

`lim-expensive`
: The minimum cost of an expensive expression in the loop invariant motion.

`min-loop-cond-split-prob`
: When FDO profile information is available, `min-loop-cond-split-prob` specifies minimum threshold for probability of semi-invariant condition statement to trigger loop split.

`iv-consider-all-candidates-bound`
: Bound on number of candidates for induction variables, below which all candidates are considered for each use in induction variable optimizations. If there are more candidates than this, only the most relevant ones are considered to avoid quadratic time complexity.

`iv-max-considered-uses`
: The induction variable optimizations give up on loops that contain more induction variable uses.

`iv-always-prune-cand-set-bound`
: If the number of candidates in the set is smaller than this value, always try to remove unnecessary ivs from the set when adding a new one.

`avg-loop-niter`
: Average number of iterations of a loop.

`dse-max-object-size`
: Maximum size (in bytes) of objects tracked bytewise by dead store elimination. Larger values may result in larger compilation times.

`dse-max-alias-queries-per-store`
: Maximum number of queries into the alias oracle per store. Larger values result in larger compilation times and may result in more removed dead stores.

`scev-max-expr-size`
: Bound on size of expressions used in the scalar evolutions analyzer. Large expressions slow the analyzer.

`scev-max-expr-complexity`
: Bound on the complexity of the expressions in the scalar evolutions analyzer. Complex expressions slow the analyzer.

`max-tree-if-conversion-phi-args`
: Maximum number of arguments in a PHI supported by TREE if conversion unless the loop is marked with simd pragma.

`vect-max-layout-candidates`
: The maximum number of possible vector layouts (such as permutations) to consider when optimizing to-be-vectorized code.

`vect-max-version-for-alignment-checks`
: The maximum number of run-time checks that can be performed when doing loop versioning for alignment in the vectorizer.

`vect-max-version-for-alias-checks`
: The maximum number of run-time checks that can be performed when doing loop versioning for alias in the vectorizer.

`vect-max-peeling-for-alignment`
: The maximum number of loop peels to enhance access alignment for vectorizer. Value -1 means no limit.

`max-iterations-to-track`
The maximum number of iterations of a loop the brute-force algorithm for analysis of the number of iterations of the loop tries to evaluate.

`hot-bb-count-fraction`
The denominator n of fraction 1/n of the maximal execution count of a basic block in the entire program that a basic block needs to at least have in order to be considered hot. The default is 10000, which means that a basic block is considered hot if its execution count is greater than 1/10000 of the maximal execution count. 0 means that it is never considered hot. Used in non-LTO mode.

`hot-bb-count-ws-permille`
The number of most executed permilles, ranging from 0 to 1000, of the profiled execution of the entire program to which the execution count of a basic block must be part of in order to be considered hot. The default is 990, which means that a basic block is considered hot if its execution count contributes to the upper 990 permilles, or 99.0%, of the profiled execution of the entire program. 0 means that it is never considered hot. Used in LTO mode.

`hot-bb-frequency-fraction`
The denominator n of fraction 1/n of the execution frequency of the entry block of a function that a basic block of this function needs to at least have in order to be considered hot. The default is 1000, which means that a basic block is considered hot in a function if it is executed more frequently than 1/1000 of the frequency of the entry block of the function. 0 means that it is never considered hot.

`unlikely-bb-count-fraction`
The denominator n of fraction 1/n of the number of profiled runs of the entire program below which the execution count of a basic block must be in order for the basic block to be considered unlikely executed. The default is 20, which means that a basic block is considered unlikely executed if it is executed in fewer than 1/20, or 5%, of the runs of the program. 0 means that it is always considered unlikely executed.

`max-predicted-iterations`
The maximum number of loop iterations we predict statically. This is useful in cases where a function contains a single loop with known bound and another loop with unknown bound. The known number of iterations is predicted correctly, while the unknown number of iterations average to roughly 10. This means that the loop without bounds appears artificially cold relative to the other one.

`builtin-expect-probability`
Control the probability of the expression having the specified value. This parameter takes a percentage (i.e. 0 ... 100) as input.

`builtin-string-cmp-inline-length`
: The maximum length of a constant string for a builtin string cmp call eligible for inlining.

`align-threshold`
: Select fraction of the maximal frequency of executions of a basic block in a function to align the basic block.

`align-loop-iterations`
: A loop expected to iterate at least the selected number of iterations is aligned.

`tracer-dynamic-coverage`
`tracer-dynamic-coverage-feedback`
: This value is used to limit superblock formation once the given percentage of executed instructions is covered. This limits unnecessary code size expansion.

: The `tracer-dynamic-coverage-feedback` parameter is used only when profile feedback is available. The real profiles (as opposed to statically estimated ones) are much less balanced allowing the threshold to be larger value.

`tracer-max-code-growth`
: Stop tail duplication once code growth has reached given percentage. This is a rather artificial limit, as most of the duplicates are eliminated later in cross jumping, so it may be set to much higher values than is the desired code growth.

`tracer-min-branch-ratio`
: Stop reverse growth when the reverse probability of best edge is less than this threshold (in percent).

`tracer-min-branch-probability`
`tracer-min-branch-probability-feedback`
: Stop forward growth if the best edge has probability lower than this threshold.

: Similarly to `tracer-dynamic-coverage` two parameters are provided. `tracer-min-branch-probability-feedback` is used for compilation with profile feedback and `tracer-min-branch-probability` compilation without. The value for compilation with profile feedback needs to be more conservative (higher) in order to make tracer effective.

`stack-clash-protection-guard-size`
: Specify the size of the operating system provided stack guard as 2 raised to *num* bytes. Higher values may reduce the number of explicit probes, but a value larger than the operating system provided guard will leave code vulnerable to stack clash style attacks.

`stack-clash-protection-probe-interval`
: Stack clash protection involves probing stack space as it is allocated. This param controls the maximum distance between probes into

the stack as 2 raised to *num* bytes. Higher values may reduce the number of explicit probes, but a value larger than the operating system provided guard will leave code vulnerable to stack clash style attacks.

`max-cse-path-length`
: The maximum number of basic blocks on path that CSE considers.

`max-cse-insns`
: The maximum number of instructions CSE processes before flushing.

`ggc-min-expand`
: GCC uses a garbage collector to manage its own memory allocation. This parameter specifies the minimum percentage by which the garbage collector's heap should be allowed to expand between collections. Tuning this may improve compilation speed; it has no effect on code generation.

  The default is 30% `+` 70% * (RAM/1GB) with an upper bound of 100% when RAM `>=` 1GB. If `getrlimit` is available, the notion of "RAM" is the smallest of actual RAM and `RLIMIT_DATA` or `RLIMIT_AS`. If GCC is not able to calculate RAM on a particular platform, the lower bound of 30% is used. Setting this parameter and `ggc-min-heapsize` to zero causes a full collection to occur at every opportunity. This is extremely slow, but can be useful for debugging.

`ggc-min-heapsize`
: Minimum size of the garbage collector's heap before it begins bothering to collect garbage. The first collection occurs after the heap expands by `ggc-min-expand`% beyond `ggc-min-heapsize`. Again, tuning this may improve compilation speed, and has no effect on code generation.

  The default is the smaller of RAM/8, RLIMIT_RSS, or a limit that tries to ensure that RLIMIT_DATA or RLIMIT_AS are not exceeded, but with a lower bound of 4096 (four megabytes) and an upper bound of 131072 (128 megabytes). If GCC is not able to calculate RAM on a particular platform, the lower bound is used. Setting this parameter very large effectively disables garbage collection. Setting this parameter and `ggc-min-expand` to zero causes a full collection to occur at every opportunity.

`max-reload-search-insns`
: The maximum number of instruction reload should look backward for equivalent register. Increasing values mean more aggressive optimization, making the compilation time increase with probably slightly better performance.

`max-cselib-memory-locations`
: The maximum number of memory locations cselib should take into account. Increasing values mean more aggressive optimization, making the compilation time increase with probably slightly better performance.

`max-sched-ready-insns`
: The maximum number of instructions ready to be issued the scheduler should consider at any given time during the first scheduling pass. Increasing values mean more thorough searches, making the compilation time increase with probably little benefit.

`max-sched-region-blocks`
: The maximum number of blocks in a region to be considered for interblock scheduling.

`max-pipeline-region-blocks`
: The maximum number of blocks in a region to be considered for pipelining in the selective scheduler.

`max-sched-region-insns`
: The maximum number of insns in a region to be considered for interblock scheduling.

`max-pipeline-region-insns`
: The maximum number of insns in a region to be considered for pipelining in the selective scheduler.

`min-spec-prob`
: The minimum probability (in percents) of reaching a source block for interblock speculative scheduling.

`max-sched-extend-regions-iters`
: The maximum number of iterations through CFG to extend regions. A value of 0 disables region extensions.

`max-sched-insn-conflict-delay`
: The maximum conflict delay for an insn to be considered for speculative motion.

`sched-spec-prob-cutoff`
: The minimal probability of speculation success (in percents), so that speculative insns are scheduled.

`sched-state-edge-prob-cutoff`
: The minimum probability an edge must have for the scheduler to save its state across it.

`sched-mem-true-dep-cost`
: Minimal distance (in CPU cycles) between store and load targeting same memory locations.

`selsched-max-lookahead`
: The maximum size of the lookahead window of selective scheduling. It is a depth of search for available instructions.

`selsched-max-sched-times`
: The maximum number of times that an instruction is scheduled during selective scheduling. This is the limit on the number of iterations through which the instruction may be pipelined.

`selsched-insns-to-rename`
: The maximum number of best instructions in the ready list that are considered for renaming in the selective scheduler.

`sms-min-sc`
: The minimum value of stage count that swing modulo scheduler generates.

`max-last-value-rtl`
: The maximum size measured as number of RTLs that can be recorded in an expression in combiner for a pseudo register as last known value of that register.

`max-combine-insns`
: The maximum number of instructions the RTL combiner tries to combine.

`max-combine-search-insns`
: The maximum number of instructions that the RTL combiner searches in order to find the next use of a given register definition. If this limit is reached without finding such a use, the combiner will stop trying to optimize the definition.

  Currently this limit only applies after certain successful combination attempts, but it could be extended to other cases in future.

`integer-share-limit`
: Small integer constants can use a shared data structure, reducing the compiler's memory usage and increasing its speed. This sets the maximum value of a shared integer constant.

`ssp-buffer-size`
: The minimum size of buffers (i.e. arrays) that receive stack smashing protection when `-fstack-protector` is used.

`min-size-for-stack-sharing`
: The minimum size of variables taking part in stack slot sharing when not optimizing.

`max-jump-thread-duplication-stmts`
: Maximum number of statements allowed in a block that needs to be duplicated when threading jumps.

`max-jump-thread-paths`
: The maximum number of paths to consider when searching for jump threading opportunities. When arriving at a block, incoming edges are only considered if the number of paths to be searched so far multiplied by the number of incoming edges does not exhaust the specified maximum number of paths to consider.

`max-fields-for-field-sensitive`
: Maximum number of fields in a structure treated in a field sensitive manner during pointer analysis.

`prefetch-latency`
: Estimate on average number of instructions that are executed before prefetch finishes. The distance prefetched ahead is proportional to this constant. Increasing this number may also lead to less streams being prefetched (see `simultaneous-prefetches`).

`simultaneous-prefetches`
: Maximum number of prefetches that can run at the same time.

`l1-cache-line-size`
: The size of cache line in L1 data cache, in bytes.

`l1-cache-size`
: The size of L1 data cache, in kilobytes.

`l2-cache-size`
: The size of L2 data cache, in kilobytes.

`prefetch-dynamic-strides`
: Whether the loop array prefetch pass should issue software prefetch hints for strides that are non-constant. In some cases this may be beneficial, though the fact the stride is non-constant may make it hard to predict when there is clear benefit to issuing these hints.

  Set to 1 if the prefetch hints should be issued for non-constant strides. Set to 0 if prefetch hints should be issued only for strides that are known to be constant and below `prefetch-minimum-stride`.

`prefetch-minimum-stride`
: Minimum constant stride, in bytes, to start using prefetch hints for. If the stride is less than this threshold, prefetch hints will not be issued.

  This setting is useful for processors that have hardware prefetchers, in which case there may be conflicts between the hardware prefetchers and the software prefetchers. If the hardware prefetchers have a maximum stride they can handle, it should be used here to improve the use of software prefetchers.

  A value of -1 means we don't have a threshold and therefore prefetch hints can be issued for any constant stride.

  This setting is only useful for strides that are known and constant.

`destructive-interference-size`
`constructive-interference-size`
: The values for the C++17 variables `std::hardware_destructive_interference_size` and `std::hardware_constructive_interference_size`. The destructive interference size is

the minimum recommended offset between two independent concurrently-accessed objects; the constructive interference size is the maximum recommended size of contiguous memory accessed together. Typically both will be the size of an L1 cache line for the target, in bytes. For a generic target covering a range of L1 cache line sizes, typically the constructive interference size will be the small end of the range and the destructive size will be the large end.

The destructive interference size is intended to be used for layout, and thus has ABI impact. The default value is not expected to be stable, and on some targets varies with `-mtune`, so use of this variable in a context where ABI stability is important, such as the public interface of a library, is strongly discouraged; if it is used in that context, users can stabilize the value using this option.

The constructive interference size is less sensitive, as it is typically only used in a '`static_assert`' to make sure that a type fits within a cache line.

See also `-Winterference-size`.

`loop-interchange-max-num-stmts`
: The maximum number of stmts in a loop to be interchanged.

`loop-interchange-stride-ratio`
: The minimum ratio between stride of two loops for interchange to be profitable.

`min-insn-to-prefetch-ratio`
: The minimum ratio between the number of instructions and the number of prefetches to enable prefetching in a loop.

`prefetch-min-insn-to-mem-ratio`
: The minimum ratio between the number of instructions and the number of memory references to enable prefetching in a loop.

`use-canonical-types`
: Whether the compiler should use the "canonical" type system. Should always be 1, which uses a more efficient internal mechanism for comparing types in C++ and Objective-C++. However, if bugs in the canonical type system are causing compilation failures, set this value to 0 to disable canonical types.

`switch-conversion-max-branch-ratio`
: Switch initialization conversion refuses to create arrays that are bigger than `switch-conversion-max-branch-ratio` times the number of branches in the switch.

`max-partial-antic-length`
: Maximum length of the partial antic set computed during the tree partial redundancy elimination optimization (`-ftree-pre`) when optimizing at `-O3` and above. For some sorts of source code the enhanced partial redundancy elimination optimization can run away,

consuming all of the memory available on the host machine. This parameter sets a limit on the length of the sets that are computed, which prevents the runaway behavior. Setting a value of 0 for this parameter allows an unlimited set length.

`rpo-vn-max-loop-depth`
Maximum loop depth that is value-numbered optimistically. When the limit hits the innermost *rpo-vn-max-loop-depth* loops and the outermost loop in the loop nest are value-numbered optimistically and the remaining ones not.

`sccvn-max-alias-queries-per-access`
Maximum number of alias-oracle queries we perform when looking for redundancies for loads and stores. If this limit is hit the search is aborted and the load or store is not considered redundant. The number of queries is algorithmically limited to the number of stores on all paths from the load to the function entry.

`ira-max-loops-num`
IRA uses regional register allocation by default. If a function contains more loops than the number given by this parameter, only at most the given number of the most frequently-executed loops form regions for regional register allocation.

`ira-max-conflict-table-size`
Although IRA uses a sophisticated algorithm to compress the conflict table, the table can still require excessive amounts of memory for huge functions. If the conflict table for a function could be more than the size in MB given by this parameter, the register allocator instead uses a faster, simpler, and lower-quality algorithm that does not require building a pseudo-register conflict table.

`ira-loop-reserved-regs`
IRA can be used to evaluate more accurate register pressure in loops for decisions to move loop invariants (see `-O3`). The number of available registers reserved for some other purposes is given by this parameter. Default of the parameter is the best found from numerous experiments.

`ira-consider-dup-in-all-alts`
Make IRA to consider matching constraint (duplicated operand number) heavily in all available alternatives for preferred register class. If it is set as zero, it means IRA only respects the matching constraint when it's in the only available alternative with an appropriate register class. Otherwise, it means IRA will check all available alternatives for preferred register class even if it has found some choice with an appropriate register class and respect the found qualified matching constraint.

`ira-simple-lra-insn-threshold`
: Approximate function insn number in 1K units triggering simple local RA.

`lra-inheritance-ebb-probability-cutoff`
: LRA tries to reuse values reloaded in registers in subsequent insns. This optimization is called inheritance. EBB is used as a region to do this optimization. The parameter defines a minimal fall-through edge probability in percentage used to add BB to inheritance EBB in LRA. The default value was chosen from numerous runs of SPEC2000 on x86-64.

`loop-invariant-max-bbs-in-loop`
: Loop invariant motion can be very expensive, both in compilation time and in amount of needed compile-time memory, with very large loops. Loops with more basic blocks than this parameter won't have loop invariant motion optimization performed on them.

`loop-max-datarefs-for-datadeps`
: Building data dependencies is expensive for very large loops. This parameter limits the number of data references in loops that are considered for data dependence analysis. These large loops are no handled by the optimizations using loop data dependencies.

`max-vartrack-size`
: Sets a maximum number of hash table slots to use during variable tracking dataflow analysis of any function. If this limit is exceeded with variable tracking at assignments enabled, analysis for that function is retried without it, after removing all debug insns from the function. If the limit is exceeded even without debug insns, var tracking analysis is completely disabled for the function. Setting the parameter to zero makes it unlimited.

`max-vartrack-expr-depth`
: Sets a maximum number of recursion levels when attempting to map variable names or debug temporaries to value expressions. This trades compilation time for more complete debug information. If this is set too low, value expressions that are available and could be represented in debug information may end up not being used; setting this higher may enable the compiler to find more complex debug expressions, but compile time and memory use may grow.

`max-debug-marker-count`
: Sets a threshold on the number of debug markers (e.g. begin stmt markers) to avoid complexity explosion at inlining or expanding to RTL. If a function has more such gimple stmts than the set limit, such stmts will be dropped from the inlined copy of a function, and from its RTL expansion.

`min-nondebug-insn-uid`
: Use uids starting at this parameter for nondebug insns. The range below the parameter is reserved exclusively for debug insns created by `-fvar-tracking-assignments`, but debug insns may get (non-overlapping) uids above it if the reserved range is exhausted.

`ipa-sra-deref-prob-threshold`
: IPA-SRA replaces a pointer which is known not be NULL with one or more new parameters only when the probability (in percent, relative to function entry) of it being dereferenced is higher than this parameter.

`ipa-sra-ptr-growth-factor`
: IPA-SRA replaces a pointer to an aggregate with one or more new parameters only when their cumulative size is less or equal to `ipa-sra-ptr-growth-factor` times the size of the original pointer parameter.

`ipa-sra-ptrwrap-growth-factor`
: Additional maximum allowed growth of total size of new parameters that ipa-sra replaces a pointer to an aggregate with, if it points to a local variable that the caller only writes to and passes it as an argument to other functions.

`ipa-sra-max-replacements`
: Maximum pieces of an aggregate that IPA-SRA tracks. As a consequence, it is also the maximum number of replacements of a formal parameter.

`sra-max-scalarization-size-Ospeed`
`sra-max-scalarization-size-Osize`
: The two Scalar Reduction of Aggregates passes (SRA and IPA-SRA) aim to replace scalar parts of aggregates with uses of independent scalar variables. These parameters control the maximum size, in storage units, of aggregate which is considered for replacement when compiling for speed (`sra-max-scalarization-size-Ospeed`) or size (`sra-max-scalarization-size-Osize`) respectively.

`sra-max-propagations`
: The maximum number of artificial accesses that Scalar Replacement of Aggregates (SRA) will track, per one local variable, in order to facilitate copy propagation.

`tm-max-aggregate-size`
: When making copies of thread-local variables in a transaction, this parameter specifies the size in bytes after which variables are saved with the logging functions as opposed to save/restore code sequence pairs. This option only applies when using `-fgnu-tm`.

`graphite-max-nb-scop-params`
: To avoid exponential effects in the Graphite loop transforms, the number of parameters in a Static Control Part (SCoP) is bounded. A value of zero can be used to lift the bound. A variable whose value is unknown at compilation time and defined outside a SCoP is a parameter of the SCoP.

`hardcfr-max-blocks`
: Disable `-fharden-control-flow-redundancy` for functions with a larger number of blocks than the specified value. Zero removes any limit.

`hardcfr-max-inline-blocks`
: Force `-fharden-control-flow-redundancy` to use out-of-line checking for functions with a larger number of basic blocks than the specified value.

`loop-block-tile-size`
: Loop blocking or strip mining transforms, enabled with `-floop-block` or `-floop-strip-mine`, strip mine each loop in the loop nest by a given number of iterations. The strip length can be changed using the `loop-block-tile-size` parameter.

`ipa-jump-function-lookups`
: Specifies number of statements visited during jump function offset discovery.

`ipa-cp-value-list-size`
: IPA-CP attempts to track all possible values and types passed to a function's parameter in order to propagate them and perform devirtualization. `ipa-cp-value-list-size` is the maximum number of values and types it stores per one formal parameter of a function.

`ipa-cp-eval-threshold`
: IPA-CP calculates its own score of cloning profitability heuristics and performs those cloning opportunities with scores that exceed `ipa-cp-eval-threshold`.

`ipa-cp-max-recursive-depth`
: Maximum depth of recursive cloning for self-recursive function.

`ipa-cp-min-recursive-probability`
: Recursive cloning only when the probability of call being executed exceeds the parameter.

`ipa-cp-recursive-freq-factor`
: The number of times interprocedural copy propagation expects recursive functions to call themselves.

`ipa-cp-recursion-penalty`
: Percentage penalty the recursive functions will receive when they are evaluated for cloning.

`ipa-cp-single-call-penalty`
: Percentage penalty functions containing a single call to another function will receive when they are evaluated for cloning.

`ipa-max-agg-items`
: IPA-CP is also capable to propagate a number of scalar values passed in an aggregate. `ipa-max-agg-items` controls the maximum number of such values per one parameter.

`ipa-cp-loop-hint-bonus`
: When IPA-CP determines that a cloning candidate would make the number of iterations of a loop known, it adds a bonus of `ipa-cp-loop-hint-bonus` to the profitability score of the candidate.

`ipa-max-loop-predicates`
: The maximum number of different predicates IPA will use to describe when loops in a function have known properties.

`ipa-max-aa-steps`
: During its analysis of function bodies, IPA-CP employs alias analysis in order to track values pointed to by function parameters. In order not spend too much time analyzing huge functions, it gives up and consider all memory clobbered after examining `ipa-max-aa-steps` statements modifying memory.

`ipa-max-switch-predicate-bounds`
: Maximal number of boundary endpoints of case ranges of switch statement. For switch exceeding this limit, IPA-CP will not construct cloning cost predicate, which is used to estimate cloning benefit, for default case of the switch statement.

`ipa-max-param-expr-ops`
: IPA-CP will analyze conditional statement that references some function parameter to estimate benefit for cloning upon certain constant value. But if number of operations in a parameter expression exceeds `ipa-max-param-expr-ops`, the expression is treated as complicated one, and is not handled by IPA analysis.

`lto-partitions`
: Specify desired number of partitions produced during WHOPR compilation. The number of partitions should exceed the number of CPUs used for compilation.

`lto-min-partition`
: Size of minimal partition for WHOPR (in estimated instructions). This prevents expenses of splitting very small programs into too many partitions.

`lto-max-partition`
: Size of max partition for WHOPR (in estimated instructions). to provide an upper bound for individual size of partition. Meant to be used only with balanced partitioning.

`lto-partition-locality-frequency-cutoff`
The denominator n of fraction 1/n of the execution frequency of callee to be cloned for a particular caller. Special value of 0 dictates to always clone without a cut-off.

`lto-partition-locality-size-cutoff`
Size cut-off for callee including inlined calls to be cloned for a particular caller.

`lto-max-locality-partition`
Maximal size of a locality partition for LTO (in estimated instructions). Value of 0 results in default value being used.

`lto-max-streaming-parallelism`
Maximal number of parallel processes used for LTO streaming.

`cxx-max-namespaces-for-diagnostic-help`
The maximum number of namespaces to consult for suggestions when C++ name lookup fails for an identifier.

`sink-frequency-threshold`
The maximum relative execution frequency (in percents) of the target block relative to a statement's original block to allow statement sinking of a statement. Larger numbers result in more aggressive statement sinking. A small positive adjustment is applied for statements with memory operands as those are even more profitable so sink.

`max-stores-to-sink`
The maximum number of conditional store pairs that can be sunk. Set to 0 if either vectorization (`-ftree-vectorize`) or if-conversion (`-ftree-loop-if-convert`) is disabled.

`case-values-threshold`
The smallest number of different values for which it is best to use a jump-table instead of a tree of conditional branches. If the value is 0, use the default for the machine.

`jump-table-max-growth-ratio-for-size`
The maximum code size growth ratio when expanding into a jump table (in percent). The parameter is used when optimizing for size.

`jump-table-max-growth-ratio-for-speed`
The maximum code size growth ratio when expanding into a jump table (in percent). The parameter is used when optimizing for speed.

`tree-reassoc-width`
Set the maximum number of instructions executed in parallel in reassociated tree. This parameter overrides target dependent heuristics used by default if has non zero value.

`sched-pressure-algorithm`
: Choose between the two available implementations of `-fsched-pressure`. Algorithm 1 is the original implementation and is the more likely to prevent instructions from being reordered. Algorithm 2 was designed to be a compromise between the relatively conservative approach taken by algorithm 1 and the rather aggressive approach taken by the default scheduler. It relies more heavily on having a regular register file and accurate register pressure classes. See `haifa-sched.cc` in the GCC sources for more details.

  The default choice depends on the target.

`max-slsr-cand-scan`
: Set the maximum number of existing candidates that are considered when seeking a basis for a new straight-line strength reduction candidate.

`asan-globals`
: Enable buffer overflow detection for global objects. This kind of protection is enabled by default if you are using `-fsanitize=address` option. To disable global objects protection use `--param asan-globals=0`.

`asan-stack`
: Enable buffer overflow detection for stack objects. This kind of protection is enabled by default when using `-fsanitize=address`. To disable stack protection use `--param asan-stack=0` option.

`asan-instrument-reads`
: Enable buffer overflow detection for memory reads. This kind of protection is enabled by default when using `-fsanitize=address`. To disable memory reads protection use `--param asan-instrument-reads=0`.

`asan-instrument-writes`
: Enable buffer overflow detection for memory writes. This kind of protection is enabled by default when using `-fsanitize=address`. To disable memory writes protection use `--param asan-instrument-writes=0` option.

`asan-memintrin`
: Enable detection for built-in functions. This kind of protection is enabled by default when using `-fsanitize=address`. To disable built-in functions protection use `--param asan-memintrin=0`.

`asan-use-after-return`
: Enable detection of use-after-return. This kind of protection is enabled by default when using the `-fsanitize=address` option. To disable it use `--param asan-use-after-return=0`.

  Note: By default the check is disabled at run time. To enable it, add `detect_stack_use_after_return=1` to the environment variable `ASAN_OPTIONS`.

`asan-instrumentation-with-call-threshold`
: If number of memory accesses in function being instrumented is greater or equal to this number, use callbacks instead of inline checks. E.g. to disable inline code use `--param asan-instrumentation-with-call-threshold=0`.

`asan-kernel-mem-intrinsic-prefix`
: If nonzero, prefix calls to `memcpy`, `memset` and `memmove` with '`__asan_`' or '`__hwasan_`' for `-fsanitize=kernel-address` or '`-fsanitize=kernel-hwaddress`', respectively.

`hwasan-instrument-stack`
: Enable hwasan instrumentation of statically sized stack-allocated variables. This kind of instrumentation is enabled by default when using `-fsanitize=hwaddress` and disabled by default when using `-fsanitize=kernel-hwaddress`. To disable stack instrumentation use `--param hwasan-instrument-stack=0`, and to enable it use `--param hwasan-instrument-stack=1`.

`hwasan-random-frame-tag`
: When using stack instrumentation, decide tags for stack variables using a deterministic sequence beginning at a random tag for each frame. With this parameter unset tags are chosen using the same sequence but beginning from 1. This is enabled by default for `-fsanitize=hwaddress` and unavailable for `-fsanitize=kernel-hwaddress`. To disable it use `--param hwasan-random-frame-tag=0`.

`hwasan-instrument-allocas`
: Enable hwasan instrumentation of dynamically sized stack-allocated variables. This kind of instrumentation is enabled by default when using `-fsanitize=hwaddress` and disabled by default when using `-fsanitize=kernel-hwaddress`. To disable instrumentation of such variables use `--param hwasan-instrument-allocas=0`, and to enable it use `--param hwasan-instrument-allocas=1`.

`hwasan-instrument-reads`
: Enable hwasan checks on memory reads. Instrumentation of reads is enabled by default for both `-fsanitize=hwaddress` and `-fsanitize=kernel-hwaddress`. To disable checking memory reads use `--param hwasan-instrument-reads=0`.

`hwasan-instrument-writes`
: Enable hwasan checks on memory writes. Instrumentation of writes is enabled by default for both `-fsanitize=hwaddress` and `-fsanitize=kernel-hwaddress`. To disable checking memory writes use `--param hwasan-instrument-writes=0`.

`hwasan-instrument-mem-intrinsics`
: Enable hwasan instrumentation of builtin functions. Instrumentation of these builtin functions is enabled by default for both `-fsanitize=hwaddress` and `-fsanitize=kernel-hwaddress`. To disable instrumentation of builtin functions use `--param hwasan-instrument-mem-intrinsics=0`.

`use-after-scope-direct-emission-threshold`
: If the size of a local variable in bytes is smaller or equal to this number, directly poison (or unpoison) shadow memory instead of using run-time callbacks.

`tsan-distinguish-volatile`
: Emit special instrumentation for accesses to volatiles.

`tsan-instrument-func-entry-exit`
: Emit instrumentation calls to __tsan_func_entry() and __tsan_func_exit().

`max-fsm-thread-path-insns`
: Maximum number of instructions to copy when duplicating blocks on a finite state automaton jump thread path.

`threader-debug`
: threader-debug=[none|all] Enables verbose dumping of the threader solver.

`parloops-chunk-size`
: Chunk size of omp schedule for loops parallelized by parloops.

`parloops-schedule`
: Schedule type of omp schedule for loops parallelized by parloops (static, dynamic, guided, auto, runtime).

`parloops-min-per-thread`
: The minimum number of iterations per thread of an innermost parallelized loop for which the parallelized variant is preferred over the single threaded one. Note that for a parallelized loop nest the minimum number of iterations of the outermost loop per thread is two.

`max-ssa-name-query-depth`
: Maximum depth of recursion when querying properties of SSA names in things like fold routines. One level of recursion corresponds to following a use-def chain.

`max-speculative-devirt-maydefs`
: The maximum number of may-defs we analyze when looking for a must-def specifying the dynamic type of an object that invokes a virtual call we may be able to devirtualize speculatively.

`ranger-debug`
: Specifies the type of debug output to be issued for ranges.

`unroll-jam-min-percent`
: The minimum percentage of memory references that must be optimized away for the unroll-and-jam transformation to be considered profitable.

`unroll-jam-max-unroll`
: The maximum number of times the outer loop should be unrolled by the unroll-and-jam transformation.

`max-rtl-if-conversion-unpredictable-cost`
: Maximum permissible cost for the sequence that would be generated by the RTL if-conversion pass for a branch that is considered unpredictable.

`max-variable-expansions-in-unroller`
: If `-fvariable-expansion-in-unroller` is used, the maximum number of times that an individual variable will be expanded during loop unrolling.

`partial-inlining-entry-probability`
: Maximum probability of the entry BB of split region (in percent relative to entry BB of the function) to make partial inlining happen.

`max-tracked-strlens`
: Maximum number of strings for which strlen optimization pass will track string lengths.

`gcse-after-reload-partial-fraction`
: The threshold ratio for performing partial redundancy elimination after reload.

`gcse-after-reload-critical-fraction`
: The threshold ratio of critical edges execution count that permit performing redundancy elimination after reload.

`max-loop-header-insns`
: The maximum number of insns in loop header duplicated by the copy loop headers pass.

`vect-epilogues-nomask`
: Enable loop epilogue vectorization using smaller vector size.

`vect-partial-vector-usage`
: Controls when the loop vectorizer considers using partial vector loads and stores as an alternative to falling back to scalar code. 0 stops the vectorizer from ever using partial vector loads and stores. 1 allows partial vector loads and stores if vectorization removes the need for the code to iterate. 2 allows partial vector loads and stores in all loops. The parameter only has an effect on targets that support partial vector loads and stores.

`vect-inner-loop-cost-factor`
: The maximum factor which the loop vectorizer applies to the cost of statements in an inner loop relative to the loop being vectorized. The factor applied is the maximum of the estimated number of iterations of the inner loop and this parameter. The default value of this parameter is 50.

`vect-induction-float`
: Enable loop vectorization of floating point inductions.

`vect-scalar-cost-multiplier`
: Apply the given multiplier % to scalar loop costing during vectorization. Increasing the cost multiplier will make vector loops more profitable.

`vrp-block-limit`
: Maximum number of basic blocks before VRP switches to a lower memory algorithm.

`vrp-sparse-threshold`
: Maximum number of basic blocks before VRP uses a sparse bitmap cache.

`vrp-switch-limit`
: Maximum number of outgoing edges in a switch before VRP will not process it.

`vrp-vector-threshold`
: Maximum number of basic blocks for VRP to use a basic cache vector.

`avoid-fma-max-bits`
: Maximum number of bits for which we avoid creating FMAs.

`fully-pipelined-fma`
: Whether the target fully pipelines FMA instructions. If non-zero, reassociation considers the benefit of parallelizing FMA's multiplication part and addition part, assuming FMUL and FMA use the same units that can also do FADD.

`sms-loop-average-count-threshold`
: A threshold on the average loop count considered by the swing modulo scheduler.

`sms-dfa-history`
: The number of cycles the swing modulo scheduler considers when checking conflicts using DFA.

`graphite-allow-codegen-errors`
: Whether codegen errors should be ICEs when `-fchecking`.

`sms-max-ii-factor`
: A factor for tuning the upper bound that swing modulo scheduler uses for scheduling a loop.

`lra-max-considered-reload-pseudos`
: The max number of reload pseudos which are considered during spilling a non-reload pseudo.

`lra-max-pseudos-points-log2-considered-for-preferences`
: The maximum `log2(number of reload pseudos * number of program points)` threshold when preferences for other reload pseudos are still considered. Taking these preferences into account helps to improve register allocation. However, for very large functions, a large value can result in significant compilation time and memory consumption. The default value is 30.

`max-pow-sqrt-depth`
: Maximum depth of sqrt chains to use when synthesizing exponentiation by a real constant.

`max-dse-active-local-stores`
: Maximum number of active local stores in RTL dead store elimination.

`asan-instrument-allocas`
: Enable asan allocas/VLAs protection.

`max-iterations-computation-cost`
: Bound on the cost of an expression to compute the number of iterations.

`max-isl-operations`
: Maximum number of isl operations, 0 means unlimited.

`graphite-max-arrays-per-scop`
: Maximum number of arrays per scop.

`max-vartrack-reverse-op-size`
: Max. size of loc list for which reverse ops should be added.

`fsm-scale-path-stmts`
: Scale factor to apply to the number of statements in a threading path crossing a loop backedge when comparing to `--param=max-jump-thread-duplication-stmts`.

`uninit-control-dep-attempts`
: Maximum number of nested calls to search for control dependencies during uninitialized variable analysis.

`uninit-max-chain-len`
: Maximum number of predicates anded for each predicate ored in the normalized predicate chain.

`uninit-max-num-chains`
: Maximum number of predicates ored in the normalized predicate chain.

`uninit-max-prune-work`
: Maximum amount of work done to prune paths where the variable is always initialized.

`sched-autopref-queue-depth`
: Hardware autoprefetcher scheduler model control flag. Number of lookahead cycles the model looks into; at ' ' only enable instruction sorting heuristic.

`loop-versioning-max-inner-insns`
: The maximum number of instructions that an inner loop can have before the loop versioning pass considers it too big to copy.

`loop-versioning-max-outer-insns`
: The maximum number of instructions that an outer loop can have before the loop versioning pass considers it too big to copy, discounting any instructions in inner loops that directly benefit from versioning.

`ssa-name-def-chain-limit`
: The maximum number of SSA_NAME assignments to follow in determining a property of a variable such as its value. This limits the number of iterations or recursive calls GCC performs when optimizing certain statements or when determining their validity prior to issuing diagnostics.

`store-merging-max-size`
: Maximum size of a single store merging region in bytes.

`store-forwarding-max-distance`
: Maximum number of instruction distance that a small store forwarded to a larger load may stall. Value '0' disables the cost checks for the avoid-store-forwarding pass.

`hash-table-verification-limit`
: The number of elements for which hash table verification is done for each searched element.

`max-find-base-term-values`
: Maximum number of VALUEs handled during a single find_base_term call.

`analyzer-max-enodes-per-program-point`
: The maximum number of exploded nodes per program point within the analyzer, before terminating analysis of that point.

`analyzer-max-constraints`
: The maximum number of constraints per state.

`analyzer-min-snodes-for-call-summary`
: The minimum number of supernodes within a function for the analyzer to consider summarizing its effects at call sites.

analyzer-max-enodes-for-full-dump
: The maximum depth of exploded nodes that should appear in a dot dump before switching to a less verbose format.

analyzer-max-recursion-depth
: The maximum number of times a callsite can appear in a call stack within the analyzer, before terminating analysis of a call that would recurse deeper.

analyzer-max-svalue-depth
: The maximum depth of a symbolic value, before approximating the value as unknown.

analyzer-max-infeasible-edges
: The maximum number of infeasible edges to reject before declaring a diagnostic as infeasible.

gimple-fe-computed-hot-bb-threshold
: The number of executions of a basic block which is considered hot. The parameter is used only in GIMPLE FE.

analyzer-bb-explosion-factor
: The maximum number of 'after supernode' exploded nodes within the analyzer per supernode, before terminating analysis.

analyzer-text-art-string-ellipsis-threshold
: The number of bytes at which to ellipsize string literals in analyzer text art diagrams.

analyzer-text-art-ideal-canvas-width
: The ideal width in characters of text art diagrams generated by the analyzer.

analyzer-text-art-string-ellipsis-head-len
: The number of literal bytes to show at the head of a string literal in text art when ellipsizing it.

analyzer-text-art-string-ellipsis-tail-len
: The number of literal bytes to show at the tail of a string literal in text art when ellipsizing it.

ranger-logical-depth
: Maximum depth of logical expression evaluation ranger will look through when evaluating outgoing edge ranges.

ranger-recompute-depth
: Maximum depth of instruction chains to consider for recomputation in the outgoing range calculator.

relation-block-limit
: Maximum number of relations the oracle will register in a basic block.

`transitive-relations-work-bound`
: Work bound when discovering transitive relations from existing relations.

`min-pagesize`
: Minimum page size for warning and early break vectorization purposes.

`openacc-kernels`
: Specify mode of OpenACC 'kernels' constructs handling. With `--param=openacc-kernels=decompose`, OpenACC 'kernels' constructs are decomposed into parts, a sequence of compute constructs, each then handled individually. This is work in progress. With `--param=openacc-kernels=parloops`, OpenACC 'kernels' constructs are handled by the '`parloops`' pass, en bloc. This is the current default.

`openacc-privatization`
: Control whether the `-fopt-info-omp-note` and applicable `-fdump-tree-*-details` options emit OpenACC privatization diagnostics. With `--param=openacc-privatization=quiet`, don't diagnose. This is the current default. With `--param=openacc-privatization=noisy`, do diagnose.

`cycle-accurate-model`
: Specifies whether GCC should assume that the scheduling description is mostly a cycle-accurate model of the target processor the code is intended to run on, in the absence of cache misses. Nonzero means that the selected scheduling model is accurate and likely describes an in-order processor, and that scheduling should aggressively spill to try and fill any pipeline bubbles. This is the current default. Zero means the scheduling description might not be available/accurate or perhaps not applicable at all, such as for modern out-of-order processors.

The following choices of *name* are available on AArch64 targets:

`aarch64-vect-compare-costs`
: When vectorizing, consider using multiple different approaches and use the cost model to choose the cheapest one. This includes:

  - Trying both SVE and Advanced SIMD, when SVE is available.
  - Trying to use 64-bit Advanced SIMD vectors for the smallest data elements, rather than using 128-bit vectors for everything.
  - Trying to use "unpacked" SVE vectors for smaller elements. This includes storing smaller elements in larger containers and accessing elements with extending loads and truncating stores.

`aarch64-float-recp-precision`
: The number of Newton iterations for calculating the reciprocal for float type. The precision of division is proportional to this param when division approximation is enabled. The default value is 1.

`aarch64-double-recp-precision`
: The number of Newton iterations for calculating the reciprocal for double type. The precision of division is proportional to this param when division approximation is enabled. The default value is 2.

`aarch64-autovec-preference`
: An old alias for `-mautovec-preference`. If both `-mautovec-preference` and `--param=aarch64-autovec-preference` are passed, the `--param` value will be used.

`aarch64-ldp-policy`
: Fine-grained policy for load pairs. With `--param=aarch64-ldp-policy=default`, use the policy of the tuning structure. This is the current default. With `--param=aarch64-ldp-policy=always`, emit ldp regardless of alignment. With `--param=aarch64-ldp-policy=never`, do not emit ldp. With `--param=aarch64-ldp-policy=aligned`, emit ldp only if the source pointer is aligned to at least double the alignment of the type.

`aarch64-stp-policy`
: Fine-grained policy for store pairs. With `--param=aarch64-stp-policy=default`, use the policy of the tuning structure. This is the current default. With `--param=aarch64-stp-policy=always`, emit stp regardless of alignment. With `--param=aarch64-stp-policy=never`, do not emit stp. With `--param=aarch64-stp-policy=aligned`, emit stp only if the source pointer is aligned to at least double the alignment of the type.

`aarch64-ldp-alias-check-limit`
: Limit on the number of alias checks performed by the AArch64 load/store pair fusion pass when attempting to form an ldp/stp. Higher values make the pass more aggressive at re-ordering loads over stores, at the expense of increased compile time.

`aarch64-ldp-writeback`
: Param to control which writeback opportunities we try to handle in the AArch64 load/store pair fusion pass. A value of zero disables writeback handling. One means we try to form pairs involving one or more existing individual writeback accesses where possible. A value of two means we also try to opportunistically form writeback opportunities by folding in trailing destructive updates of the base register used by a pair.

`aarch64-loop-vect-issue-rate-niters`
: The tuning for some AArch64 CPUs tries to take both latencies and issue rates into account when deciding whether a loop should be vectorized using SVE, vectorized using Advanced SIMD, or not vectorized at all. If this parameter is set to *n*, GCC will not use this heuristic for loops that are known to execute in fewer than *n* Advanced SIMD iterations.

`aarch64-vect-unroll-limit`
: The vectorizer will use available tuning information to determine whether it would be beneficial to unroll the main vectorized loop and by how much. This parameter set's the upper bound of how much the vectorizer will unroll the main loop. The default value is four.

The following choices of *name* are available on GCN targets:

`gcn-preferred-vectorization-factor`
: Preferred vectorization factor: '`default`', '`32`', '`64`'.

The following choices of *name* are available on i386 and x86_64 targets:

`x86-stlf-window-ninsns`
: Instructions number above which STFL stall penalty can be compensated.

`x86-stv-max-visits`
: The maximum number of use and def visits when discovering a STV chain before the discovery is aborted.

`ix86-vect-unroll-limit`
: Limit how much the autovectorizer may unroll a loop.

3.13 Program Instrumentation Options

GCC supports a number of command-line options that control adding run-time instrumentation to the code it normally generates. For example, one purpose of instrumentation is collect profiling statistics for use in finding program hot spots, code coverage analysis, or profile-guided optimizations. Another class of program instrumentation is adding run-time checking to detect programming errors like invalid pointer dereferences or out-of-bounds array accesses, as well as deliberately hostile attacks such as stack smashing or C++ vtable hijacking. There is also a general hook which can be used to implement other forms of tracing or function-level instrumentation for debug or program analysis purposes.

`-p`
`--profile`
`-fprofile`
`-pg`
: Generate extra code to write profile information suitable for the analysis program `prof` (for `-p`, `--profile`, and `-fprofile`) or `gprof` (for `-pg`). You must use this option when compiling the source files you want data about, and you must also use it when linking.

  You can use the function attribute `no_instrument_function` to suppress profiling of individual functions when compiling with these options. See Section 6.4.1.1 [Common Function Attributes], page 622.

`-fprofile-arcs`
: Add code so that program flow *arcs* are instrumented. During execution the program records how many times each branch and call is executed and how many times it is taken or returns. On targets that support constructors with

priority support, profiling properly handles constructors, destructors and C++ constructors (and destructors) of classes which are used as a type of a global variable.

When the compiled program exits it saves this data to a file called `auxname.gcda` for each source file. The data may be used for profile-directed optimizations (`-fbranch-probabilities`), or for test coverage analysis (`-ftest-coverage`). Each object file's *auxname* is generated from the name of the output file, if explicitly specified and it is not the final executable, otherwise it is the basename of the source file. In both cases any suffix is removed (e.g. `foo.gcda` for input file `dir/foo.c`, or `dir/foo.gcda` for output file specified as `-o dir/foo.o`).

Note that if a command line directly links source files, the corresponding *.gcda* files will be prefixed with the unsuffixed name of the output file. E.g. `gcc a.c b.c -o binary` would generate `binary-a.gcda` and `binary-b.gcda` files.

`-fcondition-coverage`

Add code so that program conditions are instrumented. During execution the program records what terms in a conditional contributes to a decision, which can be used to verify that all terms in a Boolean function are tested and have an independent effect on the outcome of a decision. The result can be read with `gcov --conditions`.

`-fpath-coverage`

Add code so that the paths taken are tracked. During execution the program records the prime paths taken. The number of paths grows very fast with complexity, and to avoid exploding compile times GCC will give up instrumentation if the approximate number of paths exceeds the limit controlled by `-fpath-coverage-limit`. The result can be read with `gcov --prime-paths --prime-paths-lines --prime-paths-source`, See [gcov prime paths example], page 1109.

`-fpath-coverage-limit=limit`

The threshold at which point `-fpath-coverage` gives up on instrumenting a function. This limit is approximate and conservative, as GCC uses a pessimistic heuristic which slightly overcounts the running number of paths, and gives up if the threshold is reached before finding all the paths. This option is not for fine grained control over which functions to instrument - rather it is intended to limit the effect of path explosion and keep compile times reasonable. The default is *250000*.

See Section 11.5 [Cross-profiling], page 1113.

`--coverage`
`-coverage`

This option is used to compile and link code instrumented for coverage analysis. The options `-coverage` and `--coverage` are equivalent; both are a synonym for `-fprofile-arcs -ftest-coverage` (when compiling) and `-lgcov` (when linking). See the documentation for those options for more details.

- Compile the source files with `-fprofile-arcs` plus optimization and code generation options. For test coverage analysis, use the additional `-ftest-coverage` option. You do not need to profile every source file in a program.
- Compile the source files additionally with `-fprofile-abs-path` to create absolute path names in the `.gcno` files. This allows `gcov` to find the correct sources in projects where compilations occur with different working directories.
- Link your object files with `-lgcov` or `-fprofile-arcs` (the latter implies the former).
- Run the program on a representative workload to generate the arc profile information. This may be repeated any number of times. You can run concurrent instances of your program, and provided that the file system supports locking, the data files will be correctly updated. Unless a strict ISO C dialect option is in effect, `fork` calls are detected and correctly handled without double counting.

  Moreover, an object file can be recompiled multiple times and the corresponding `.gcda` file merges as long as the source file and the compiler options are unchanged.
- For profile-directed optimizations, compile the source files again with the same optimization and code generation options plus `-fbranch-probabilities` (see Section 3.12 [Options that Control Optimization], page 194).
- For test coverage analysis, use `gcov` to produce human readable information from the `.gcno` and `.gcda` files. Refer to the `gcov` documentation for further information.

With `-fprofile-arcs`, for each function of your program GCC creates a program flow graph, then finds a spanning tree for the graph. Only arcs that are not on the spanning tree have to be instrumented: the compiler adds code to count the number of times that these arcs are executed. When an arc is the only exit or only entrance to a block, the instrumentation code can be added to the block; otherwise, a new basic block must be created to hold the instrumentation code.

With `-fcondition-coverage`, for each conditional in your program GCC creates a bitset and records the exercised boolean values that have an independent effect on the outcome of that expression.

With `-fpath-coverage`, GCC finds and enumerates and records the taken prime paths of each function, unless the number of paths would exceed the limit controlled by `-fpath-coverage-limit`. If the limit is exceeded the function is not instrumented as if `-fpath-coverage` was not used. A prime path is the longest sequence of unique blocks, except possibly the first and last, which is not a subpath of any other path.

`-ftest-coverage`

Produce a notes file that the `gcov` code-coverage utility (see Chapter 11 [`gcov`—a Test Coverage Program], page 1095) can use to show program coverage. Each source file's note file is called `*auxname*.gcno`. Refer to the `-fprofile-arcs` option above for a description of *auxname* and instructions on how to generate test coverage data. Coverage data matches the source files more closely if you do not optimize.

`-fprofile-abs-path`

Automatically convert relative source file names to absolute path names in the `.gcno` files. This allows `gcov` to find the correct sources in projects where compilations occur with different working directories.

`-fprofile-dir=`*path*

Set the directory to search for the profile data files in to *path*. This option affects only the profile data generated by `-fprofile-generate`, `-ftest-coverage`, `-fprofile-arcs` and used by `-fprofile-use` and `-fbranch-probabilities` and its related options. Both absolute and relative paths can be used. By default, GCC uses the current directory as *path*, thus the profile data file appears in the same directory as the object file. In order to prevent the file name clashing, if the object file name is not an absolute path, we mangle the absolute path of the `*sourcename*.gcda` file and use it as the file name of a `.gcda` file. See details about the file naming in `-fprofile-arcs`. See similar option `-fprofile-note`.

When an executable is run in a massive parallel environment, it is recommended to save profile to different folders. That can be done with variables in *path* that are exported during run-time:

`%p` process ID.

`%q{VAR}` value of environment variable *VAR*

`-fprofile-generate`
`-fprofile-generate=`*path*

Enable options usually used for instrumenting application to produce profile useful for later recompilation with profile feedback based optimization. You must use `-fprofile-generate` both when compiling and when linking your program.

The following options are enabled: `-fprofile-arcs`, `-fprofile-values`, `-finline-functions`, and `-fipa-bit-cp`.

If *path* is specified, GCC looks at the *path* to find the profile feedback data files. See `-fprofile-dir`.

To optimize the program based on the collected profile information, use `-fprofile-use`. See Section 3.12 [Optimize Options], page 194, for more information.

`-fprofile-info-section`
`-fprofile-info-section=`*name*

Register the profile information in the specified section instead of using a constructor/destructor. The section name is *name* if it is specified, otherwise the section name defaults to `.gcov_info`. A pointer to the profile information generated by `-fprofile-arcs` is placed in the specified section for each translation unit. This option disables the profile information registration through a constructor and it disables the profile information processing through a destructor. This option is not intended to be used in hosted environments such as GNU/Linux. It targets freestanding environments (for example embedded systems) with limited resources which do not support constructors/destructors or the C library file I/O.

The linker could collect the input sections in a continuous memory block and define start and end symbols. A GNU linker script example which defines a linker output section follows:

```
  .gcov_info      :
  {
    PROVIDE (__gcov_info_start = .);
    KEEP (*(.gcov_info))
    PROVIDE (__gcov_info_end = .);
  }
```

The program could dump the profiling information registered in this linker set for example like this:

```
#include <gcov.h>
#include <stdio.h>
#include <stdlib.h>

extern const struct gcov_info *const __gcov_info_start[];
extern const struct gcov_info *const __gcov_info_end[];

static void
dump (const void *d, unsigned n, void *arg)
{
  const unsigned char *c = d;

  for (unsigned i = 0; i < n; ++i)
    printf ("%02x", c[i]);
}

static void
filename (const char *f, void *arg)
{
  __gcov_filename_to_gcfn (f, dump, arg );
}

static void *
allocate (unsigned length, void *arg)
{
  return malloc (length);
}

static void
dump_gcov_info (void)
{
  const struct gcov_info *const *info = __gcov_info_start;
  const struct gcov_info *const *end = __gcov_info_end;

  /* Obfuscate variable to prevent compiler optimizations.  */
```

```
  __asm__ ("" : "+r" (info));

  while (info != end)
  {
    void *arg = NULL;
    __gcov_info_to_gcda (*info, filename, dump, allocate, arg);
    putchar ('\n');
    ++info;
  }
}

int
main (void)
{
  dump_gcov_info ();
  return 0;
}
```

The `merge-stream` subcommand of `gcov-tool` may be used to deserialize the data stream generated by the `__gcov_filename_to_gcfn` and `__gcov_info_to_gcda` functions and merge the profile information into `.gcda` files on the host filesystem.

`-fprofile-note=`*`path`*
: If *path* is specified, GCC saves `.gcno` file into *path* location. If you combine the option with multiple source files, the `.gcno` file will be overwritten.

`-fprofile-prefix-path=`*`path`*
: This option can be used in combination with `profile-generate=`*profile_dir* and `profile-use=`*profile_dir* to inform GCC where is the base directory of built source tree. By default *profile_dir* will contain files with mangled absolute paths of all object files in the built project. This is not desirable when directory used to build the instrumented binary differs from the directory used to build the binary optimized with profile feedback because the profile data will not be found during the optimized build. In such setups `-fprofile-prefix-path=`*path* with *path* pointing to the base directory of the build can be used to strip the irrelevant part of the path and keep all file names relative to the main build directory.

`-fprofile-prefix-map=`*`old`*`=`*`new`*
: When compiling files residing in directory *`old`*, record profiling information (with `--coverage`) describing them as if the files resided in directory *`new`* instead. See also `-ffile-prefix-map` and `-fcanon-prefix-map`.

`-fprofile-update=`*`method`*
: Alter the update method for an application instrumented for profile feedback based optimization. The *method* argument should be one of '`single`', '`atomic`' or '`prefer-atomic`'. The first one is useful for single-threaded applications, while the second one prevents profile corruption by emitting thread-safe code.

: **Warning:** When an application does not properly join all threads (or creates an detached thread), a profile file can be still corrupted.

: Using '`prefer-atomic`' would be transformed either to '`atomic`', when supported by a target, or to '`single`' otherwise. The GCC driver automatically selects 'prefer-atomic' when -pthread is present in the command line, otherwise the default method is 'single'.

If 'atomic' is selected, then the profile information is updated using atomic operations on a best-effort basis. Ideally, the profile information is updated through atomic operations in hardware. If the target platform does not support the required atomic operations in hardware, however, libatomic is available, then the profile information is updated through calls to libatomic. If the target platform neither supports the required atomic operations in hardware nor libatomic, then the profile information is not atomically updated and a warning is issued. In this case, the obtained profiling information may be corrupt for multi-threaded applications.

For performance reasons, if 64-bit counters are used for the profiling information and the target platform only supports 32-bit atomic operations in hardware, then the performance critical profiling updates are done using two 32-bit atomic operations for each counter update. If a signal interrupts these two operations updating a counter, then the profiling information may be in an inconsistent state.

-fprofile-filter-files=*regex*

Instrument only functions from files whose name matches any of the regular expressions (separated by semi-colons).

For example, -fprofile-filter-files=main\.c;module.*\.c will instrument only main.c and all C files starting with 'module'.

-fprofile-exclude-files=*regex*

Instrument only functions from files whose name does not match any of the regular expressions (separated by semi-colons).

For example, -fprofile-exclude-files=/usr/.* will prevent instrumentation of all files that are located in the /usr/ folder.

-fprofile-reproducible=[multithreaded|parallel-runs|serial]

Control level of reproducibility of profile gathered by -fprofile-generate. This makes it possible to rebuild program with same outcome which is useful, for example, for distribution packages.

With -fprofile-reproducible=serial the profile gathered by -fprofile-generate is reproducible provided the trained program behaves the same at each invocation of the train run, it is not multi-threaded and profile data streaming is always done in the same order. Note that profile streaming happens at the end of program run but also before fork function is invoked.

Note that it is quite common that execution counts of some part of programs depends, for example, on length of temporary file names or memory space randomization (that may affect hash-table collision rate). Such non-reproducible part of programs may be annotated by no_instrument_function function attribute. gcov-dump with -l can be used to dump gathered data and verify that they are indeed reproducible.

With -fprofile-reproducible=parallel-runs collected profile stays reproducible regardless the order of streaming of the data into gcda files. This setting makes it possible to run multiple instances of instrumented program in parallel (such as with `make -j`). This reduces quality of gathered data, in particular of indirect call profiling.

`-fsanitize=address`

Enable AddressSanitizer, a fast memory error detector. Memory access instructions are instrumented to detect out-of-bounds and use-after-free bugs. The option enables `-fsanitize-address-use-after-scope`. See `https://github.com/google/sanitizers/wiki/AddressSanitizer` for more details. The run-time behavior can be influenced using the `ASAN_OPTIONS` environment variable. When set to `help=1`, the available options are shown at startup of the instrumented program. See `https://github.com/google/sanitizers/wiki/AddressSanitizerFlags#run-time-flags` for a list of supported options. The option cannot be combined with `-fsanitize=thread` or `-fsanitize=hwaddress`. Note that the only targets `-fsanitize=hwaddress` is currently supported on are x86-64 (only with `-mlam=u48` or `-mlam=u57` options) and AArch64, in both cases only in ABIs with 64-bit pointers.

When compiling with `-fsanitize=address`, you should also use `-g` to produce more meaningful output. To get more accurate stack traces, it is possible to use options such as `-O0`, `-O1`, or `-Og` (which, for instance, prevent most function inlining), `-fno-optimize-sibling-calls` (which prevents optimizing sibling and tail recursive calls; this option is implicit for `-O0`, `-O1`, or `-Og`), or `-fno-ipa-icf` (which disables Identical Code Folding for functions). Using `-fno-omit-frame-pointer` also improves stack traces. Since multiple runs of the program may yield backtraces with different addresses due to ASLR (Address Space Layout Randomization), it may be desirable to turn ASLR off. On Linux, this can be achieved with '``setarch `uname -m` -R ./prog``'.

`-fsanitize=kernel-address`

Enable AddressSanitizer for Linux kernel. See `https://github.com/google/kernel-sanitizers` for more details.

`-fsanitize=hwaddress`

Enable Hardware-assisted AddressSanitizer, which uses a hardware ability to ignore the top byte of a pointer to allow the detection of memory errors with a low memory overhead. Memory access instructions are instrumented to detect out-of-bounds and use-after-free bugs. The option enables `-fsanitize-address-use-after-scope`. See `https://clang.llvm.org/docs/HardwareAssistedAddressSanitizerDesign.html` for more details. The run-time behavior can be influenced using the `HWASAN_OPTIONS` environment variable. When set to `help=1`, the available options are shown at startup of the instrumented program. The option cannot be combined with `-fsanitize=thread` or `-fsanitize=address`, and is currently only available on AArch64.

`-fsanitize=kernel-hwaddress`

Enable Hardware-assisted AddressSanitizer for compilation of the Linux kernel. Similar to `-fsanitize=kernel-address` but using an alternate instrumentation method, and similar to `-fsanitize=hwaddress` but with instrumentation differences necessary for compiling the Linux kernel. These differences are to avoid hwasan library initialization calls and to account for the stack pointer having a different value in its top byte.

Note: This option has different defaults to the `-fsanitize=hwaddress`. Instrumenting the stack and alloca calls are not on by default but are still possible by specifying the command-line options `--param hwasan-instrument-stack=1` and `--param hwasan-instrument-allocas=1` respectively. Using a random frame tag is not implemented for kernel instrumentation.

`-fsanitize=pointer-compare`

Instrument comparison operation (`<`, `<=`, `>`, `>=`) with pointer operands. The option must be combined with either `-fsanitize=kernel-address` or `-fsanitize=address` The option cannot be combined with `-fsanitize=thread`. Note: By default the check is disabled at run time. To enable it, add `detect_invalid_pointer_pairs=2` to the environment variable `ASAN_OPTIONS`. Using `detect_invalid_pointer_pairs=1` detects invalid operation only when both pointers are non-null.

`-fsanitize=pointer-subtract`

Instrument subtraction with pointer operands. The option must be combined with either `-fsanitize=kernel-address` or `-fsanitize=address` The option cannot be combined with `-fsanitize=thread`. Note: By default the check is disabled at run time. To enable it, add `detect_invalid_pointer_pairs=2` to the environment variable `ASAN_OPTIONS`. Using `detect_invalid_pointer_pairs=1` detects invalid operation only when both pointers are non-null.

`-fsanitize=shadow-call-stack`

Enable ShadowCallStack, a security enhancement mechanism used to protect programs against return address overwrites (e.g. stack buffer overflows.) It works by saving a function's return address to a separately allocated shadow call stack in the function prologue and restoring the return address from the shadow call stack in the function epilogue. Instrumentation only occurs in functions that need to save the return address to the stack.

Currently it only supports the aarch64 platform. It is specifically designed for linux kernels that enable the CONFIG_SHADOW_CALL_STACK option. For the user space programs, runtime support is not currently provided in libc and libgcc. Users who want to use this feature in user space need to provide their own support for the runtime. It should be noted that this may cause the ABI rules to be broken.

On aarch64, the instrumentation makes use of the platform register `x18`. This generally means that any code that may run on the same thread as code compiled with ShadowCallStack must be compiled with the flag `-ffixed-x18`, otherwise functions compiled without `-ffixed-x18` might clobber `x18` and so corrupt the shadow stack pointer.

Also, because there is no userspace runtime support, code compiled with ShadowCallStack cannot use exception handling. Use `-fno-exceptions` to turn off exceptions.

See `https://clang.llvm.org/docs/ShadowCallStack.html` for more details.

`-fsanitize=thread`
: Enable ThreadSanitizer, a fast data race detector. Memory access instructions are instrumented to detect data race bugs. See `https://github.com/google/sanitizers/wiki#threadsanitizer` for more details. The run-time behavior can be influenced using the `TSAN_OPTIONS` environment variable; see `https://github.com/google/sanitizers/wiki/ThreadSanitizerFlags` for a list of supported options. The option cannot be combined with `-fsanitize=address`, `-fsanitize=leak`.

  When compiling with `-fsanitize=thread`, you should also use `-g` to produce more meaningful output.

  Note that sanitized atomic builtins cannot throw exceptions when operating on invalid memory addresses with non-call exceptions (`-fnon-call-exceptions`).

`-fsanitize=leak`
: Enable LeakSanitizer, a memory leak detector. This option only matters for linking of executables. The executable is linked against a library that overrides `malloc` and other allocator functions. See `https://github.com/google/sanitizers/wiki/AddressSanitizerLeakSanitizer` for more details. The run-time behavior can be influenced using the `LSAN_OPTIONS` environment variable. The option cannot be combined with `-fsanitize=thread`.

`-fsanitize=undefined`
: Enable UndefinedBehaviorSanitizer, a fast undefined behavior detector. Various computations are instrumented to detect undefined behavior at runtime. See `https://clang.llvm.org/docs/UndefinedBehaviorSanitizer.html` for more details. The run-time behavior can be influenced using the `UBSAN_OPTIONS` environment variable. Current suboptions are:

  `-fsanitize=shift`
  : This option enables checking that the result of a shift operation is not undefined. Note that what exactly is considered undefined differs slightly between C and C++, as well as between ISO C90 and C99, etc. This option has two suboptions, `-fsanitize=shift-base` and `-fsanitize=shift-exponent`.

  `-fsanitize=shift-exponent`
  : This option enables checking that the second argument of a shift operation is not negative and is smaller than the precision of the promoted first argument.

  `-fsanitize=shift-base`
  : If the second argument of a shift operation is within range, check that the result of a shift operation is not undefined. Note that what exactly is considered undefined differs slightly between C and C++, as well as between ISO C90 and C99, etc.

  `-fsanitize=integer-divide-by-zero`
  : Detect integer division by zero.

`-fsanitize=unreachable`
: With this option, the compiler turns the `__builtin_unreachable` call into a diagnostics message call instead. When reaching the `__builtin_unreachable` call, the behavior is undefined.

`-fsanitize=vla-bound`
: This option instructs the compiler to check that the size of a variable length array is positive.

`-fsanitize=null`
: This option enables pointer checking. Particularly, the application built with this option turned on will issue an error message when it tries to dereference a NULL pointer, or if a reference (possibly an rvalue reference) is bound to a NULL pointer, or if a method is invoked on an object pointed by a NULL pointer.

`-fsanitize=return`
: This option enables return statement checking. Programs built with this option turned on will issue an error message when the end of a non-void function is reached without actually returning a value. This option works in C++ only.

`-fsanitize=signed-integer-overflow`
: This option enables signed integer overflow checking. We check that the result of `+`, `*`, and both unary and binary `-` does not overflow in the signed arithmetics. This also detects `INT_MIN / -1` signed division. Note, integer promotion rules must be taken into account. That is, the following is not an overflow:

```
signed char a = SCHAR_MAX;
a++;
```

`-fsanitize=bounds`
: This option enables instrumentation of array bounds. Various out of bounds accesses are detected. Flexible array members, flexible array member-like arrays, and initializers of variables with static storage are not instrumented, with the exception of flexible array member-like arrays for which `-fstrict-flex-arrays` or `-fstrict-flex-arrays=` options or `strict_flex_array` attributes say they shouldn't be treated like flexible array member-like arrays.

`-fsanitize=bounds-strict`
: This option enables strict instrumentation of array bounds. Most out of bounds accesses are detected, including flexible array member-like arrays. Initializers of variables with static storage are not instrumented.

`-fsanitize=alignment`
: This option enables checking of alignment of pointers when they are dereferenced, or when a reference is bound to insufficiently aligned target, or when a method or constructor is invoked on insufficiently aligned object.

`-fsanitize=object-size`
: This option enables instrumentation of memory references using the `__builtin_dynamic_object_size` function. Various out of bounds pointer accesses are detected.

`-fsanitize=float-divide-by-zero`
: Detect floating-point division by zero. Unlike other similar options, `-fsanitize=float-divide-by-zero` is not enabled by `-fsanitize=undefined`, since floating-point division by zero can be a legitimate way of obtaining infinities and NaNs.

`-fsanitize=float-cast-overflow`
: This option enables floating-point type to integer conversion checking. We check that the result of the conversion does not overflow. Unlike other similar options, `-fsanitize=float-cast-overflow` is not enabled by `-fsanitize=undefined`. This option does not work well with `FE_INVALID` exceptions enabled.

`-fsanitize=nonnull-attribute`
: This option enables instrumentation of calls, checking whether null values are not passed to arguments marked as requiring a non-null value by the `nonnull` function attribute.

`-fsanitize=returns-nonnull-attribute`
: This option enables instrumentation of return statements in functions marked with `returns_nonnull` function attribute, to detect returning of null values from such functions.

`-fsanitize=bool`
: This option enables instrumentation of loads from bool. If a value other than 0/1 is loaded, a run-time error is issued.

`-fsanitize=enum`
: This option enables instrumentation of loads from an enum type. If a value outside the range of values for the enum type is loaded, a run-time error is issued.

`-fsanitize=vptr`
: This option enables instrumentation of C++ member function calls, member accesses and some conversions between pointers to base and derived classes, to verify the referenced object has the correct dynamic type.

`-fsanitize=pointer-overflow`
: This option enables instrumentation of pointer arithmetics. If the pointer arithmetics overflows, a run-time error is issued.

`-fsanitize=builtin`
: This option enables instrumentation of arguments to selected builtin functions. If an invalid value is passed to such arguments, a run-time error is issued. E.g. passing 0 as the argument to `__builtin_ctz` or `__builtin_clz` invokes undefined behavior and is diagnosed by this option.

Note that sanitizers tend to increase the rate of false positive warnings, most notably those around `-Wmaybe-uninitialized`. We recommend against combining `-Werror` and [the use of] sanitizers.

While `-ftrapv` causes traps for signed overflows to be emitted, `-fsanitize=undefined` gives a diagnostic message. This currently works only for the C family of languages.

`-fno-sanitize=all`
: This option disables all previously enabled sanitizers. `-fsanitize=all` is not allowed, as some sanitizers cannot be used together.

`-fasan-shadow-offset=`*number*
: This option forces GCC to use custom shadow offset in AddressSanitizer checks. It is useful for experimenting with different shadow memory layouts in Kernel AddressSanitizer.

`-fsanitize-sections=`*s1*`,`*s2*`,...`
: Sanitize global variables in selected user-defined sections. *si* may contain wildcards.

`-fsanitize-recover`[`=`*opts*]
: `-fsanitize-recover=` controls error recovery mode for sanitizers mentioned in comma-separated list of *opts*. Enabling this option for a sanitizer component causes it to attempt to continue running the program as if no error happened. This means multiple runtime errors can be reported in a single program run, and the exit code of the program may indicate success even when errors have been reported. The `-fno-sanitize-recover=` option can be used to alter this behavior: only the first detected error is reported and program then exits with a non-zero exit code.

Currently this feature only works for `-fsanitize=undefined` (and its suboptions except for `-fsanitize=unreachable` and `-fsanitize=return`), `-fsanitize=float-cast-overflow`, `-fsanitize=float-divide-by-zero`, `-fsanitize=bounds-strict`, `-fsanitize=kernel-address` and `-fsanitize=address`. For these sanitizers error recovery is turned on by default, except `-fsanitize=address`, for which this feature is experimental. `-fsanitize-recover=all` and `-fno-sanitize-recover=all` is also accepted, the former enables recovery for all sanitizers that support it, the latter disables recovery for all sanitizers that support it.

Even if a recovery mode is turned on the compiler side, it needs to be also enabled on the runtime library side, otherwise the failures are still fatal. The runtime library defaults to `halt_on_error=0` for ThreadSanitizer and UndefinedBehaviorSanitizer, while default value for AddressSanitizer is `halt_on_error=1`. This can be overridden through setting the `halt_on_error` flag in the corresponding environment variable.

Syntax without an explicit *opts* parameter is deprecated. It is equivalent to specifying an *opts* list of:

```
undefined,float-cast-overflow,float-divide-by-zero,bounds-strict
```

`-fsanitize-address-use-after-scope`
: Enable sanitization of local variables to detect use-after-scope bugs. The option sets `-fstack-reuse` to 'none'.

`-fsanitize-trap`[=*opts*]
: The `-fsanitize-trap=` option instructs the compiler to report for sanitizers mentioned in comma-separated list of *opts* undefined behavior using `__builtin_trap` rather than a `libubsan` library routine. If this option is enabled for certain sanitizer, it takes precedence over the `-fsanitizer-recover=` for that sanitizer, `__builtin_trap` will be emitted and be fatal regardless of whether recovery is enabled or disabled using `-fsanitize-recover=`.

  The advantage of this is that the `libubsan` library is not needed and is not linked in, so this is usable even in freestanding environments.

  Currently this feature works with `-fsanitize=undefined` (and its suboptions except for `-fsanitize=vptr`), `-fsanitize=float-cast-overflow`, `-fsanitize=float-divide-by-zero` and `-fsanitize=bounds-strict`. `-fsanitize-trap=all` can be also specified, which enables it for `undefined` suboptions, `-fsanitize=float-cast-overflow`, `-fsanitize=float-divide-by-zero` and `-fsanitize=bounds-strict`. If `-fsanitize-trap=undefined` or `-fsanitize-trap=all` is used and `-fsanitize=vptr` is enabled on the command line, the instrumentation is silently ignored as the instrumentation always needs `libubsan` support, `-fsanitize-trap=vptr` is not allowed.

`-fsanitize-undefined-trap-on-error`
: The `-fsanitize-undefined-trap-on-error` option is deprecated equivalent of `-fsanitize-trap=all`.

`-fsanitize-coverage=trace-pc`
: Enable coverage-guided fuzzing code instrumentation. Inserts a call to `__sanitizer_cov_trace_pc` into every basic block.

`-fsanitize-coverage=trace-cmp`
: Enable dataflow guided fuzzing code instrumentation. Inserts a call to `__sanitizer_cov_trace_cmp1`, `__sanitizer_cov_trace_cmp2`, `__sanitizer_cov_trace_cmp4` or `__sanitizer_cov_trace_cmp8` for integral comparison with both operands variable or `__sanitizer_cov_trace_const_cmp1`, `__sanitizer_cov_trace_const_cmp2`, `__sanitizer_cov_trace_const_cmp4` or `__sanitizer_cov_trace_const_cmp8` for integral comparison with one operand constant, `__sanitizer_cov_trace_cmpf` or `__sanitizer_cov_trace_cmpd` for float or double comparisons and `__sanitizer_cov_trace_switch` for switch statements.

`-fcf-protection=`[`full`|`branch`|`return`|`none`|`check`]
`-fcf-protection`
: Enable code instrumentation to increase program security by checking that target addresses of control-flow transfer instructions (such as indirect function call, function return, indirect jump) are valid. This prevents diverting the flow of control to an unexpected target. This is intended to protect against such threats as Return-oriented Programming (ROP), and similarly call/jmp-oriented programming (COP/JOP).

The `-fcf-protection=` keywords are interpreted as follows.

The value `branch` tells the compiler to implement checking of validity of control-flow transfer at the point of indirect branch instructions, i.e. call/jmp instructions.

The value `return` implements checking of validity at the point of returning from a function.

The value `full` is an alias for specifying both `branch` and `return`.

The value `check` is used for the final link with link-time optimization (LTO). An error is issued if LTO object files are compiled with different `-fcf-protection` values. The value `check` is ignored at the compile time.

The value `none` turns off instrumentation.

`-fcf-protection` is an alias for `-fcf-protection=full`. To override a previous `-fcf-protection` option on the command line, add `-fcf-protection=none` and then `-fcf-protection=`*kind*.

The macro `__CET__` is defined when `-fcf-protection` is used. The first bit of `__CET__` is set to 1 for the value `branch` and the second bit of `__CET__` is set to 1 for the `return`.

You can also use the `nocf_check` attribute to identify which functions and calls should be skipped from instrumentation (see Section 6.4.1 [Function Attributes], page 621).

Currently the x86 GNU/Linux target provides an implementation based on Intel Control-flow Enforcement Technology (CET) which works for i686 processor or newer.

`-fharden-compares`

For every logical test that survives gimple optimizations and is *not* the condition in a conditional branch (for example, conditions tested for conditional moves, or to store in boolean variables), emit extra code to compute and verify the reversed condition, and to call `__builtin_trap` if the results do not match. Use with '`-fharden-conditional-branches`' to cover all conditionals.

`-fharden-conditional-branches`

For every non-vectorized conditional branch that survives gimple optimizations, emit extra code to compute and verify the reversed condition, and to call `__builtin_trap` if the result is unexpected. Use with '`-fharden-compares`' to cover all conditionals.

`-fharden-control-flow-redundancy`

Emit extra code to set booleans when entering basic blocks, and to verify and trap, at function exits, when the booleans do not form an execution path that is compatible with the control flow graph.

Verification takes place before returns, before mandatory tail calls (see below) and, optionally, before escaping exceptions with `-fhardcfr-check-exceptions`, before returning calls with `-fhardcfr-check-returning-calls`, and before noreturn calls with `-fhardcfr-check-noreturn-calls`). Tuning options `--param hardcfr-max-blocks` and `--param hardcfr-max-inline-blocks` are available.

Tail call optimization takes place too late to affect control flow redundancy, but calls annotated as mandatory tail calls by language front-ends, and any calls marked early enough as potential tail calls would also have verification issued before the call, but these possibilities are merely theoretical, as these conditions can only be met when using custom compiler plugins.

`-fhardcfr-skip-leaf`
Disable `-fharden-control-flow-redundancy` in leaf functions.

`-fhardcfr-check-exceptions`
When `-fharden-control-flow-redundancy` is active, check the recorded execution path against the control flow graph at exception escape points, as if the function body was wrapped with a cleanup handler that performed the check and reraised. This option is enabled by default; use `-fno-hardcfr-check-exceptions` to disable it.

`-fhardcfr-check-returning-calls`
When `-fharden-control-flow-redundancy` is active, check the recorded execution path against the control flow graph before any function call immediately followed by a return of its result, if any, so as to not prevent tail-call optimization, whether or not it is ultimately optimized to a tail call.

This option is enabled by default whenever sibling call optimizations are enabled (see `-foptimize-sibling-calls`), but it can be enabled (or disabled, using its negated form) explicitly, regardless of the optimizations.

`-fhardcfr-check-noreturn-calls=`[`always`|`no-xthrow`|`nothrow`|`never`]
When `-fharden-control-flow-redundancy` is active, check the recorded execution path against the control flow graph before `noreturn` calls, either all of them (`always`), those that aren't expected to return control to the caller through an exception (`no-xthrow`, the default), those that may not return control to the caller through an exception either (`nothrow`), or none of them (`never`).

Checking before a `noreturn` function that may return control to the caller through an exception may cause checking to be performed more than once, if the exception is caught in the caller, whether by a handler or a cleanup. When `-fhardcfr-check-exceptions` is also enabled, the compiler will avoid associating a `noreturn` call with the implicitly-added cleanup handler, since it would be redundant with the check performed before the call, but other handlers or cleanups in the function, if activated, will modify the recorded execution path and check it again when another checkpoint is hit. The checkpoint may even be another `noreturn` call, so checking may end up performed multiple times.

Various optimizers may cause calls to be marked as `noreturn` and/or `nothrow`, even in the absence of the corresponding attributes, which may affect the placement of checks before calls, as well as the addition of implicit cleanup handlers for them. This unpredictability, and the fact that raising and reraising exceptions frequently amounts to implicitly calling `noreturn` functions, have made `no-xthrow` the default setting for this option: it excludes from the `noreturn` treatment only internal functions used to (re)raise exceptions, that are not affected by these optimizations.

`-fhardened`

Enable a set of flags for C and C++ that improve the security of the generated code without affecting its ABI. The precise flags enabled may change between major releases of GCC, but are currently:

```
-D_FORTIFY_SOURCE=3
-D_GLIBCXX_ASSERTIONS
-ftrivial-auto-var-init=zero
-fPIE  -pie  -Wl,-z,relro,-z,now
-fstack-protector-strong
-fstack-clash-protection
-fcf-protection=full (x86 GNU/Linux only)
```

The list of options enabled by `-fhardened` can be generated using the `--help=hardened` option.

When the system glibc is older than 2.35, `-D_FORTIFY_SOURCE=2` is used instead.

This option is intended to be used in production builds, not merely in debug builds.

Currently, `-fhardened` is only supported on GNU/Linux targets.

`-fhardened` only enables a particular option if it wasn't already specified anywhere on the command line. For instance, `-fhardened -fstack-protector` will only enable `-fstack-protector`, but not `-fstack-protector-strong`.

`-fstack-protector`

Emit extra code to check for buffer overflows, such as stack smashing attacks. This is done by adding a guard variable to functions with vulnerable objects. This includes functions that call `alloca`, and functions with buffers larger than or equal to 8 bytes. The guards are initialized when a function is entered and then checked when the function exits. If a guard check fails, an error message is printed and the program exits. Only variables that are actually allocated on the stack are considered, optimized away variables or variables allocated in registers don't count.

`-fstack-protector-all`

Like `-fstack-protector` except that all functions are protected.

`-fstack-protector-strong`

Like `-fstack-protector` but includes additional functions to be protected — those that have local array definitions, or have references to local frame addresses. Only variables that are actually allocated on the stack are considered, optimized away variables or variables allocated in registers don't count.

`-fstack-protector-explicit`

Like `-fstack-protector` but only protects those functions which have the `stack_protect` attribute.

`-fstack-check`

Generate code to verify that you do not go beyond the boundary of the stack. You should specify this flag if you are running in an environment with multiple threads, but you only rarely need to specify it in a single-threaded environment since stack overflow is automatically detected on nearly all systems if there is only one stack.

Note that this switch does not actually cause checking to be done; the operating system or the language runtime must do that. The switch causes generation of code to ensure that they see the stack being extended.

You can additionally specify a string parameter: '`no`' means no checking, '`generic`' means force the use of old-style checking, '`specific`' means use the best checking method and is equivalent to bare `-fstack-check`.

Old-style checking is a generic mechanism that requires no specific target support in the compiler but comes with the following drawbacks:

1. Modified allocation strategy for large objects: they are always allocated dynamically if their size exceeds a fixed threshold. Note this may change the semantics of some code.
2. Fixed limit on the size of the static frame of functions: when it is topped by a particular function, stack checking is not reliable and a warning is issued by the compiler.
3. Inefficiency: because of both the modified allocation strategy and the generic implementation, code performance is hampered.

Note that old-style stack checking is also the fallback method for '`specific`' if no target support has been added in the compiler.

'`-fstack-check=`' is designed for Ada's needs to detect infinite recursion and stack overflows. '`specific`' is an excellent choice when compiling Ada code. It is not generally sufficient to protect against stack-clash attacks. To protect against those you want '`-fstack-clash-protection`'.

`-fstack-clash-protection`

Generate code to prevent stack clash style attacks. When this option is enabled, the compiler will only allocate one page of stack space at a time and each page is accessed immediately after allocation. Thus, it prevents allocations from jumping over any stack guard page provided by the operating system.

Most targets do not fully support stack clash protection. However, on those targets `-fstack-clash-protection` will protect dynamic stack allocations. `-fstack-clash-protection` may also provide limited protection for static stack allocations if the target supports `-fstack-check=specific`.

`-fstack-limit-register=`*reg*
`-fstack-limit-symbol=`*sym*
`-fno-stack-limit`

Generate code to ensure that the stack does not grow beyond a certain value, either the value of a register or the address of a symbol. If a larger stack is required, a signal is raised at run time. For most targets, the signal is raised before the stack overruns the boundary, so it is possible to catch the signal without taking special precautions.

For instance, if the stack starts at absolute address '`0x80000000`' and grows downwards, you can use the flags `-fstack-limit-symbol=__stack_limit` and

`-Wl,--defsym,__stack_limit=0x7ffe0000` to enforce a stack limit of 128KB. Note that this may only work with the GNU linker.

You can locally override stack limit checking by using the `no_stack_limit` function attribute (see Section 6.4.1 [Function Attributes], page 621).

`-fsplit-stack`
: Generate code to automatically split the stack before it overflows. The resulting program has a discontiguous stack which can only overflow if the program is unable to allocate any more memory. This is most useful when running threaded programs, as it is no longer necessary to calculate a good stack size to use for each thread. This is currently only implemented for the x86 targets running GNU/Linux.

  When code compiled with `-fsplit-stack` calls code compiled without `-fsplit-stack`, there may not be much stack space available for the latter code to run. If compiling all code, including library code, with `-fsplit-stack` is not an option, then the linker can fix up these calls so that the code compiled without `-fsplit-stack` always has a large stack. Support for this is implemented in the gold linker in GNU Binutils release 2.21 and later.

`-fstrub=disable`
: Disable stack scrubbing entirely, ignoring any `strub` attributes. See See Section 6.4.3.1 [Common Type Attributes], page 715.

`-fstrub=strict`
: Functions default to `strub` mode `disabled`, and apply `strict`ly the restriction that only functions associated with `strub-callable` modes (`at-calls`, `callable` and `always_inline internal`) are `callable` by functions with `strub`-enabled modes (`at-calls` and `internal`).

`-fstrub=relaxed`
: Restore the default stack scrub (`strub`) setting, namely, `strub` is only enabled as required by `strub` attributes associated with function and data types. `Relaxed` means that strub contexts are only prevented from calling functions explicitly associated with `strub` mode `disabled`. This option is only useful to override other `-fstrub=*` options that precede it in the command line.

`-fstrub=at-calls`
: Enable `at-calls` `strub` mode where viable. The primary use of this option is for testing. It exercises the `strub` machinery in scenarios strictly local to a translation unit. This `strub` mode modifies function interfaces, so any function that is visible to other translation units, or that has its address taken, will *not* be affected by this option. Optimization options may also affect viability. See the `strub` attribute documentation for details on viability and eligibility requirements.

`-fstrub=internal`
: Enable `internal` `strub` mode where viable. The primary use of this option is for testing. This option is intended to exercise thoroughly parts of the `strub` machinery that implement the less efficient, but interface-preserving

strub mode. Functions that would not be affected by this option are quite uncommon.

-fstrub=all
: Enable some strub mode where viable. When both strub modes are viable, at-calls is preferred. -fdump-ipa-strubm adds function attributes that tell which mode was selected for each function. The primary use of this option is for testing, to exercise thoroughly the strub machinery.

-fvtable-verify=[std|preinit|none]
: This option is only available when compiling C++ code. It turns on (or off, if using -fvtable-verify=none) the security feature that verifies at run time, for every virtual call, that the vtable pointer through which the call is made is valid for the type of the object, and has not been corrupted or overwritten. If an invalid vtable pointer is detected at run time, an error is reported and execution of the program is immediately halted.

  This option causes run-time data structures to be built at program startup, which are used for verifying the vtable pointers. The options 'std' and 'preinit' control the timing of when these data structures are built. In both cases the data structures are built before execution reaches main. Using -fvtable-verify=std causes the data structures to be built after shared libraries have been loaded and initialized. -fvtable-verify=preinit causes them to be built before shared libraries have been loaded and initialized.

  If this option appears multiple times in the command line with different values specified, 'none' takes highest priority over both 'std' and 'preinit'; 'preinit' takes priority over 'std'.

-fvtv-debug
: When used in conjunction with -fvtable-verify=std or -fvtable-verify=preinit, causes debug versions of the runtime functions for the vtable verification feature to be called. This flag also causes the compiler to log information about which vtable pointers it finds for each class. This information is written to a file named vtv_set_ptr_data.log in the directory named by the environment variable VTV_LOGS_DIR if that is defined or the current working directory otherwise.

  Note: This feature *appends* data to the log file. If you want a fresh log file, be sure to delete any existing one.

-fvtv-counts
: This is a debugging flag. When used in conjunction with -fvtable-verify=std or -fvtable-verify=preinit, this causes the compiler to keep track of the total number of virtual calls it encounters and the number of verifications it inserts. It also counts the number of calls to certain run-time library functions that it inserts and logs this information for each compilation unit. The compiler writes this information to a file named vtv_count_data.log in the directory named by the environment variable VTV_LOGS_DIR if that is defined or the current working directory otherwise. It also counts the size of the vtable pointer sets for each class, and writes this information to vtv_class_set_sizes.log in the same directory.

Note: This feature *appends* data to the log files. To get fresh log files, be sure to delete any existing ones.

`-finstrument-functions`

Generate instrumentation calls for entry and exit to functions. Just after function entry and just before function exit, the following profiling functions are called with the address of the current function and its call site. (On some platforms, `__builtin_return_address` does not work beyond the current function, so the call site information may not be available to the profiling functions otherwise.)

```
void __cyg_profile_func_enter (void *this_fn,
                               void *call_site);
void __cyg_profile_func_exit  (void *this_fn,
                               void *call_site);
```

The first argument is the address of the start of the current function, which may be looked up exactly in the symbol table.

This instrumentation is also done for functions expanded inline in other functions. The profiling calls indicate where, conceptually, the inline function is entered and exited. This means that addressable versions of such functions must be available. If all your uses of a function are expanded inline, this may mean an additional expansion of code size. If you use `extern inline` in your C code, an addressable version of such functions must be provided. (This is normally the case anyway, but if you get lucky and the optimizer always expands the functions inline, you might have gotten away without providing static copies.)

A function may be given the attribute `no_instrument_function`, in which case this instrumentation is not done. This can be used, for example, for the profiling functions listed above, high-priority interrupt routines, and any functions from which the profiling functions cannot safely be called (perhaps signal handlers, if the profiling routines generate output or allocate memory). See Section 6.4.1.1 [Common Function Attributes], page 622.

`-finstrument-functions-once`

This is similar to `-finstrument-functions`, but the profiling functions are called only once per instrumented function, i.e. the first profiling function is called after the first entry into the instrumented function and the second profiling function is called before the exit corresponding to this first entry.

The definition of `once` for the purpose of this option is a little vague because the implementation is not protected against data races. As a result, the implementation only guarantees that the profiling functions are called at *least* once per process and at *most* once per thread, but the calls are always paired, that is to say, if a thread calls the first function, then it will call the second function, unless it never reaches the exit of the instrumented function.

`-finstrument-functions-exclude-file-list=`*`file`*`,`*`file`*`,...`

Set the list of functions that are excluded from instrumentation (see the description of `-finstrument-functions`). If the file that contains a function definition matches with one of *file*, then that function is not instrumented. The match is done on substrings: if the *file* parameter is a substring of the file name, it is considered to be a match.

For example:

```
-finstrument-functions-exclude-file-list=/bits/stl,include/sys
```

excludes any inline function defined in files whose pathnames contain `/bits/stl` or `include/sys`.

If, for some reason, you want to include letter '`,`' in one of *sym*, write '`\,`'. For example, `-finstrument-functions-exclude-file-list='\,\,tmp'` (note the single quote surrounding the option).

`-finstrument-functions-exclude-function-list=`*sym*`,`*sym*`,...`

This is similar to `-finstrument-functions-exclude-file-list`, but this option sets the list of function names to be excluded from instrumentation. The function name to be matched is its user-visible name, such as `vector<int> blah(const vector<int> &)`, not the internal mangled name (e.g., `_Z4blahRSt6vectorIiSaIiEE`). The match is done on substrings: if the *sym* parameter is a substring of the function name, it is considered to be a match. For C99 and C++ extended identifiers, the function name must be given in UTF-8, not using universal character names.

`-fpatchable-function-entry=`*N*`[,`*M*`]`

Generate *N* NOPs right at the beginning of each function, with the function entry point before the *M*th NOP. If *M* is omitted, it defaults to `0` so the function entry points to the address just at the first NOP. The NOP instructions reserve extra space which can be used to patch in any desired instrumentation at run time, provided that the code segment is writable. The amount of space is controllable indirectly via the number of NOPs; the NOP instruction used corresponds to the instruction emitted by the internal GCC back-end interface `gen_nop`. This behavior is target-specific and may also depend on the architecture variant and/or other compilation options.

For run-time identification, the starting addresses of these areas, which correspond to their respective function entries minus *M*, are additionally collected in the `__patchable_function_entries` section of the resulting binary.

Note that the value of `__attribute__ ((patchable_function_entry (N,M)))` takes precedence over command-line option `-fpatchable-function-entry=N,M`. This can be used to increase the area size or to remove it completely on a single function. If `N=0`, no pad location is recorded.

The NOP instructions are inserted at—and maybe before, depending on *M*—the function entry address, even before the prologue. On PowerPC with the ELFv2 ABI, for a function with dual entry points, the local entry point is this function entry address by default. See the `-msplit-patch-nops` option to change this.

The maximum value of *N* and *M* is 65535. On PowerPC with the ELFv2 ABI, for a function with dual entry points, the supported values for *M* are 0, 2, 6 and 14 when not using `-msplit-patch-nops`.

3.14 Options Controlling the Preprocessor

These options control the C preprocessor, which is run on each C source file before actual compilation.

If you use the `-E` option, nothing is done except preprocessing. Some of these options make sense only together with `-E` because they cause the preprocessor output to be unsuitable for actual compilation.

In addition to the options listed here, there are a number of options to control search paths for include files documented in Section 3.17 [Directory Options], page 312. Options to control preprocessor diagnostics are listed in Section 3.9 [Warning Options], page 100.

`-D` *`name`*
`--define-macro=`*`name`*
`--define-macro` *`name`*

Predefine *name* as a macro, with definition `1`.

`-D` *`name=definition`*
`--define-macro=`*`name=definition`*
`--define-macro` *`name=definition`*

The contents of *definition* are tokenized and processed as if they appeared during translation phase three in a '`#define`' directive. In particular, the definition is truncated by embedded newline characters.

If you are invoking the preprocessor from a shell or shell-like program you may need to use the shell's quoting syntax to protect characters such as spaces that have a meaning in the shell syntax.

If you wish to define a function-like macro on the command line, write its argument list with surrounding parentheses before the equals sign (if any). Parentheses are meaningful to most shells, so you should quote the option. With `sh` and `csh`, `-D'`*`name`*`(`*`args...`*`)=`*`definition`*`'` works.

`-D` and `-U` options are processed in the order they are given on the command line. All `-imacros` *`file`* and `-include` *`file`* options are processed after all `-D` and `-U` options.

`-U` *`name`*
`--undefine-macro=`*`name`*
`--undefine-macro` *`name`*

Cancel any previous definition of *name*, either built in or provided with a `-D` option.

`-include` *`file`*
`--include=`*`file`*
`--include` *`file`*

Process *file* as if `#include "file"` appeared as the first line of the primary source file. However, the first directory searched for *file* is the preprocessor's working directory *instead of* the directory containing the main source file. If not found there, it is searched for in the remainder of the `#include "..."` search chain as normal.

If multiple `-include` options are given, the files are included in the order they appear on the command line.

`-imacros` *file*
`--imacros=`*file*
`--imacros` *file*

Exactly like `-include`, except that any output produced by scanning *file* is thrown away. Macros it defines remain defined. This allows you to acquire all the macros from a header without also processing its declarations.

All files specified by `-imacros` are processed before all files specified by `-include`.

`-undef` Do not predefine any system-specific or GCC-specific macros. The standard predefined macros remain defined.

`-pthread` Define additional macros required for using the POSIX threads library. You should use this option consistently for both compilation and linking. This option is supported on GNU/Linux targets, most other Unix derivatives, and also on x86 Cygwin and MinGW targets.

`-M`

`--dependencies`

Instead of outputting the result of preprocessing, output a rule suitable for `make` describing the dependencies of the main source file. The preprocessor outputs one `make` rule containing the object file name for that source file, a colon, and the names of all the included files, including those coming from `-include` or `-imacros` command-line options.

Unless specified explicitly (with `-MT` or `-MQ`), the object file name consists of the name of the source file with any suffix replaced with object file suffix and with any leading directory parts removed. If there are many included files then the rule is split into several lines using '\'-newline. The rule has no commands.

This option does not suppress the preprocessor's debug output, such as `-dM`. To avoid mixing such debug output with the dependency rules you should explicitly specify the dependency output file with `-MF`, or use an environment variable like `DEPENDENCIES_OUTPUT` (see Section 3.22 [Environment Variables], page 579). Debug output is still sent to the regular output stream as normal.

Passing `-M` to the driver implies `-E`, and suppresses warnings with an implicit `-w`.

`-MM`
`--user-dependencies`

Like `-M` but do not mention header files that are found in system header directories, nor header files that are included, directly or indirectly, from such a header.

This implies that the choice of angle brackets or double quotes in an '`#include`' directive does not in itself determine whether that header appears in `-MM` dependency output.

`-MF` *file* When used with `-M` or `-MM`, specifies a file to write the dependencies to. If no `-MF` switch is given the preprocessor sends the rules to the same place it would send preprocessed output.

When used with the driver options `-MD` or `-MMD`, `-MF` overrides the default dependency output file.

If *file* is `-`, then the dependencies are written to `stdout`.

`-MG`
`--print-missing-file-dependencies`
In conjunction with an option such as `-M` requesting dependency generation, `-MG` assumes missing header files are generated files and adds them to the dependency list without raising an error. The dependency filename is taken directly from the `#include` directive without prepending any path. `-MG` also suppresses preprocessed output, as a missing header file renders this useless.

This feature is used in automatic updating of makefiles.

`-Mno-modules`
Disable dependency generation for compiled module interfaces.

`-MP` This option instructs CPP to add a phony target for each dependency other than the main file, causing each to depend on nothing. These dummy rules work around errors `make` gives if you remove header files without updating the `Makefile` to match.

This is typical output:

```
test.o: test.c test.h

test.h:
```

`-MT target`
Change the target of the rule emitted by dependency generation. By default CPP takes the name of the main input file, deletes any directory components and any file suffix such as '`.c`', and appends the platform's usual object suffix. The result is the target.

An `-MT` option sets the target to be exactly the string you specify. If you want multiple targets, you can specify them as a single argument to `-MT`, or use multiple `-MT` options.

For example, `-MT '$(objpfx)foo.o'` might give

```
$(objpfx)foo.o: foo.c
```

`-MQ target`
Same as `-MT`, but it quotes any characters which are special to Make. `-MQ '$(objpfx)foo.o'` gives

```
$$(objpfx)foo.o: foo.c
```

The default target is automatically quoted, as if it were given with `-MQ`.

`-MD`
`--write-dependencies`
`-MD` is equivalent to `-M -MF file`, except that `-E` is not implied. The driver determines *file* based on whether an `-o` option is given. If it is, the driver uses its argument but with a suffix of `.d`, otherwise it takes the name of the input file, removes any directory components and suffix, and applies a `.d` suffix.

If `-MD` is used in conjunction with `-E`, any `-o` switch is understood to specify the dependency output file (see [-MF], page 298), but if used without `-E`, each `-o` is understood to specify a target object file.

Since `-E` is not implied, `-MD` can be used to generate a dependency output file as a side effect of the compilation process.

`-MMD`
`--write-user-dependencies`
: Like `-MD` except mention only user header files, not system header files.

`-fpreprocessed`
: Indicate to the preprocessor that the input file has already been preprocessed. This suppresses things like macro expansion, trigraph conversion, escaped newline splicing, and processing of most directives. The preprocessor still recognizes and removes comments, so that you can pass a file preprocessed with `-C` to the compiler without problems. In this mode the integrated preprocessor is little more than a tokenizer for the front ends.

  `-fpreprocessed` is implicit if the input file has one of the extensions '`.i`', '`.ii`' or '`.mi`'. These are the extensions that GCC uses for preprocessed files created by `-save-temps`.

`-fdirectives-only`
: When preprocessing, handle directives, but do not expand macros.

  The option's behavior depends on the `-E` and `-fpreprocessed` options.

  With `-E`, preprocessing is limited to the handling of directives such as `#define`, `#ifdef`, and `#error`. Other preprocessor operations, such as macro expansion and trigraph conversion are not performed. In addition, the `-dD` option is implicitly enabled.

  With `-fpreprocessed`, predefinition of command line and most builtin macros is disabled. Macros such as `__LINE__`, which are contextually dependent, are handled normally. This enables compilation of files previously preprocessed with `-E -fdirectives-only`.

  With both `-E` and `-fpreprocessed`, the rules for `-fpreprocessed` take precedence. This enables full preprocessing of files previously preprocessed with `-E -fdirectives-only`.

`-fdollars-in-identifiers`
: Accept '`$`' in identifiers.

`-fextended-identifiers`
: Accept universal character names and extended characters in identifiers. This option is enabled by default for C99 (and later C standard versions) and C++.

`-fno-canonical-system-headers`
: When preprocessing, do not shorten system header paths with canonicalization.

`-fmax-include-depth=`*`depth`*
: Set the maximum depth of the nested #include. The default is 200.

`-fsearch-include-path[=kind]`
Look for input files on the #include path, not just the current directory. This is particularly useful with C++20 modules, for which both header units and module interface units need to be compiled directly:

```
g++ -c -std=c++20 -fmodules -fsearch-include-path bits/stdc++.h bits/std.cc
```

kind defaults to '`user`', which looks on the `#include "..."` search path; you can also explicitly specify '`system`' for the `#include <...>` search path.

`-ftabstop=width`
Set the distance between tab stops. This helps the preprocessor report correct column numbers in warnings or errors, even if tabs appear on the line. If the value is less than 1 or greater than 100, the option is ignored. The default is 8.

`-ftrack-macro-expansion[=level]`
Track locations of tokens across macro expansions. This allows the compiler to emit diagnostic about the current macro expansion stack when a compilation error occurs in a macro expansion. Using this option makes the preprocessor and the compiler consume more memory. The *level* parameter can be used to choose the level of precision of token location tracking thus decreasing the memory consumption if necessary. Value '`0`' of *level* de-activates this option. Value '`1`' tracks tokens locations in a degraded mode for the sake of minimal memory overhead. In this mode all tokens resulting from the expansion of an argument of a function-like macro have the same location. Value '`2`' tracks tokens locations completely. This value is the most memory hungry. When this option is given no argument, the default parameter value is '`2`'.

Note that `-ftrack-macro-expansion=2` is activated by default.

`-fmacro-prefix-map=old=new`
When preprocessing files residing in directory *old*, expand the `__FILE__` and `__BASE_FILE__` macros as if the files resided in directory *new* instead. This can be used to change an absolute path to a relative path by using `.` for *new* which can result in more reproducible builds that are location independent. This option also affects `__builtin_FILE()` during compilation. See also `-ffile-prefix-map` and `-fcanon-prefix-map`.

`-fexec-charset=charset`
Set the execution character set, used for string and character constants. The default is UTF-8. *charset* can be any encoding supported by the system's `iconv` library routine.

`-fwide-exec-charset=charset`
Set the wide execution character set, used for wide string and character constants. The default is one of UTF-32BE, UTF-32LE, UTF-16BE, or UTF-16LE, whichever corresponds to the width of `wchar_t` and the big-endian or little-endian byte order being used for code generation. As with `-fexec-charset`, *charset* can be any encoding supported by the system's `iconv` library routine; however, you will have problems with encodings that do not fit exactly in `wchar_t`.

`-finput-charset=charset`
: Set the input character set, used for translation from the character set of the input file to the source character set used by GCC. If the locale does not specify, or GCC cannot get this information from the locale, the default is UTF-8. This can be overridden by either the locale or this command-line option. Currently the command-line option takes precedence if there's a conflict. *charset* can be any encoding supported by the system's `iconv` library routine.

`-fpch-deps`
: When using precompiled headers (see Section 3.23 [Precompiled Headers], page 582), this flag causes the dependency-output flags to also list the files from the precompiled header's dependencies. If not specified, only the precompiled header are listed and not the files that were used to create it, because those files are not consulted when a precompiled header is used.

`-fpch-preprocess`
: This option allows use of a precompiled header (see Section 3.23 [Precompiled Headers], page 582) together with `-E`. It inserts a special `#pragma`, `#pragma GCC pch_preprocess "filename"` in the output to mark the place where the precompiled header was found, and its *filename*. When `-fpreprocessed` is in use, GCC recognizes this `#pragma` and loads the PCH.

  This option is off by default, because the resulting preprocessed output is only really suitable as input to GCC. It is switched on by `-save-temps`.

  You should not write this `#pragma` in your own code, but it is safe to edit the filename if the PCH file is available in a different location. The filename may be absolute or it may be relative to GCC's current directory.

`-fworking-directory`
: Enable generation of linemarkers in the preprocessor output that let the compiler know the current working directory at the time of preprocessing. When this option is enabled, the preprocessor emits, after the initial linemarker, a second linemarker with the current working directory followed by two slashes. GCC uses this directory, when it's present in the preprocessed input, as the directory emitted as the current working directory in some debugging information formats. This option is implicitly enabled if debugging information is enabled, but this can be inhibited with the negated form `-fno-working-directory`. If the `-P` flag is present in the command line, this option has no effect, since no `#line` directives are emitted whatsoever.

`-C`
`--comments`
: Do not discard comments. All comments are passed through to the output file, except for comments in processed directives, which are deleted along with the directive.

  You should be prepared for side effects when using `-C`; it causes the preprocessor to treat comments as tokens in their own right. For example, comments appearing at the start of what would be a directive line have the effect of turning that line into an ordinary source line, since the first token on the line is no longer a '`#`'.

`-CC`
`--comments-in-macros`

Do not discard comments, including during macro expansion. This is like `-C`, except that comments contained within macros are also passed through to the output file where the macro is expanded.

In addition to the side effects of the `-C` option, the `-CC` option causes all C++-style comments inside a macro to be converted to C-style comments. This is to prevent later use of that macro from inadvertently commenting out the remainder of the source line.

The `-CC` option is generally used to support lint comments.

`-P`
`--no-line-commands`

Inhibit generation of linemarkers in the output from the preprocessor. This might be useful when running the preprocessor on something that is not C code, and will be sent to a program which might be confused by the linemarkers.

`-traditional`
`--traditional`
`-traditional-cpp`
`--traditional-cpp`

Try to imitate the behavior of pre-standard C preprocessors, as opposed to ISO C preprocessors. See the GNU CPP manual for details.

Note that GCC does not otherwise attempt to emulate a pre-standard C compiler, and these options are only supported with the `-E` switch, or when invoking CPP explicitly.

`-trigraphs`
`--trigraphs`

Support ISO C trigraphs. These are three-character sequences, all starting with '`??`', that are defined by ISO C to stand for single characters. For example, '`??/`' stands for '`\`', so '`'??/n'`' is a character constant for a newline.

The nine trigraphs and their replacements are

```
Trigraph:       ??(  ??)  ??<  ??>  ??=  ??/  ??'  ??!  ??-
Replacement:      [    ]    {    }    #    \    ^    |    ~
```

By default, GCC ignores trigraphs, but in standard-conforming modes it converts them. See the `-std` and `-ansi` options.

`-remap` Enable special code to work around file systems which only permit very short file names, such as MS-DOS.

`-H`
`--trace-includes`

Print the name of each header file used, in addition to other normal activities. Each name is indented to show how deep in the '`#include`' stack it is. Precompiled header files are also printed, even if they are found to be invalid; an invalid precompiled header file is printed with '`...x`' and a valid one with '`...!`' .

`-dletters`
`--dump=letters`
`--dump letters`

Says to make debugging dumps during compilation as specified by *letters*. The flags documented here are those relevant to the preprocessor. Other *letters* are interpreted by the compiler proper, or reserved for future versions of GCC, and so are silently ignored. If you specify *letters* whose behavior conflicts, the result is undefined. See Section 3.19 [Developer Options], page 326, for more information.

`-dM`
`--dump=M`
Instead of the normal output, generate a list of '`#define`' directives for all the macros defined during the execution of the preprocessor, including predefined macros. This gives you a way of finding out what is predefined in your version of the preprocessor. Assuming you have no file `foo.h`, the command

```
touch foo.h; cpp -dM foo.h
```

shows all the predefined macros.

If you use `-dM` without the `-E` option, `-dM` is interpreted as a synonym for `-fdump-rtl-mach`. See Section "Developer Options" in `gcc`.

`-dD`
`--dump=D`
Like `-dM` except that it outputs *both* the '`#define`' directives and the result of preprocessing. Both kinds of output go to the standard output file.

`-dN`
`--dump=N`
Like `-dD`, but emit only the macro names, not their expansions.

`-dI`
`--dump=I`
Output '`#include`' directives in addition to the result of preprocessing.

`-dU`
`--dump=U`
Like `-dD` except that only macros that are expanded, or whose definedness is tested in preprocessor directives, are output; the output is delayed until the use or test of the macro; and '`#undef`' directives are also output for macros tested but undefined at the time.

`-fdebug-cpp`

This option is only useful for debugging GCC. When used from CPP or with `-E`, it dumps debugging information about location maps. Every token in the output is preceded by the dump of the map its location belongs to.

When used from GCC without `-E`, this option has no effect.

`-Wp,option`

You can use `-Wp,option` to bypass the compiler driver and pass *option* directly through to the preprocessor. If *option* contains commas, it is split into multiple options at the commas. However, many options are modified, translated or interpreted by the compiler driver before being passed to the preprocessor, and `-Wp` forcibly bypasses this phase. The preprocessor's direct interface is undocumented and subject to change, so whenever possible you should avoid using `-Wp` and let the driver handle the options instead.

`-Xpreprocessor` *option*
: Pass *option* as an option to the preprocessor. You can use this to supply system-specific preprocessor options that GCC does not recognize.

  If you want to pass an option that takes an argument, you must use `-Xpreprocessor` twice, once for the option and once for the argument.

`-no-integrated-cpp`
`--no-integrated-cpp`
: Perform preprocessing as a separate pass before compilation. By default, GCC performs preprocessing as an integrated part of input tokenization and parsing. If this option is provided, the appropriate language front end (`cc1`, `cc1plus`, or `cc1obj` for C, C++, and Objective-C, respectively) is instead invoked twice, once for preprocessing only and once for actual compilation of the preprocessed input. This option may be useful in conjunction with the `-B` or `-wrapper` options to specify an alternate preprocessor or perform additional processing of the program source between normal preprocessing and compilation.

3.15 Passing Options to the Assembler

You can pass options to the assembler.

`-Wa,`*option*
: Pass *option* as an option to the assembler. If *option* contains commas, it is split into multiple options at the commas.

`-Xassembler` *option*
`--for-assembler=`*option*
`--for-assembler` *option*
: Pass *option* as an option to the assembler. You can use this to supply system-specific assembler options that GCC does not recognize.

  If you want to pass an option that takes an argument, you must use `-Xassembler` twice, once for the option and once for the argument.

3.16 Options for Linking

These options come into play when the compiler links object files into an executable output file. They are meaningless if the compiler is not doing a link step.

object-file-name
: A file name that does not end in a special recognized suffix is considered to name an object file or library. (Object files are distinguished from libraries by the linker according to the file contents.) If linking is done, these object files are used as input to the linker.

`-c`
`-S`
`-E` If any of these options is used, then the linker is not run, and object file names should not be used as arguments. See Section 3.2 [Overall Options], page 34.

`-flink-libatomic`
Enable linking of libatomic if it's supported by target, and is enabled by default. The negative form `-fno-link-libatomic` can be used to explicitly disable linking of libatomic.

`-flinker-output=`*type*
This option controls code generation of the link-time optimizer. By default the linker output is automatically determined by the linker plugin. For debugging the compiler and if incremental linking with a non-LTO object file is desired, it may be useful to control the type manually.

If *type* is '`exec`', code generation produces a static binary. In this case `-fpic` and `-fpie` are both disabled.

If *type* is '`dyn`', code generation produces a shared library. In this case `-fpic` or `-fPIC` is preserved, but not enabled automatically. This allows to build shared libraries without position-independent code on architectures where this is possible, i.e. on x86.

If *type* is '`pie`', code generation produces an `-fpie` executable. This results in similar optimizations as '`exec`' except that `-fpie` is not disabled if specified at compilation time.

If *type* is '`rel`', the compiler assumes that incremental linking is done. The sections containing intermediate code for link-time optimization are merged, pre-optimized, and output to the resulting object file. In addition, if `-ffat-lto-objects` is specified, binary code is produced for future non-LTO linking. The object file produced by incremental linking is smaller than a static library produced from the same object files. At link time the result of incremental linking also loads faster than a static library assuming that the majority of objects in the library are used.

Finally '`nolto-rel`' configures the compiler for incremental linking where code generation is forced, a final binary is produced, and the intermediate code for later link-time optimization is stripped. When multiple object files are linked together the resulting code is better optimized than with link-time optimizations disabled (for example, cross-module inlining happens), but most of the benefits of whole-program optimizations are lost.

During the incremental link (by `-r`) the linker plugin defaults to `rel`. GNU Binutils 2.44 or later is needed to incrementally link LTO objects and non-LTO objects into a single mixed object file. If any of the object files in an incremental link cannot be used for link-time optimization, the linker plugin issues a warning and uses '`nolto-rel`'. To maintain whole-program optimization, link such objects into a static library instead.

`-fuse-ld=bfd`
Use the `bfd` linker instead of the default linker.

`-fuse-ld=gold`
: Use the `gold` linker instead of the default linker.

`-fuse-ld=lld`
: Use the LLVM `lld` linker instead of the default linker.

`-fuse-ld=mold`
: Use the Modern Linker (`mold`) instead of the default linker.

`-fuse-ld=wild`
: Use the Wild linker (`wild`) instead of the default linker.

`-l`*`library`*
`-l` *`library`*
: Search the library named *library* when linking. (The second alternative with the library as a separate argument is only for POSIX compliance and is not recommended.)

The `-l` option is passed directly to the linker by GCC. Refer to your linker documentation for exact details. The general description below applies to the GNU linker.

The linker searches a standard list of directories for the library. The directories searched include several standard system directories plus any that you specify with `-L`.

Static libraries are archives of object files, and have file names like `lib`*`library`*`.a`. Some targets also support shared libraries, which typically have names like `lib`*`library`*`.so`. If both static and shared libraries are found, the linker gives preference to linking with the shared library unless the `-static` option is used.

It makes a difference where in the command you write this option; the linker searches and processes libraries and object files in the order they are specified. Thus, '`foo.o -lz bar.o`' searches library '`z`' after file `foo.o` but before `bar.o`. If `bar.o` refers to functions in '`z`', those functions may not be loaded.

`-lobjc`
: You need this special case of the `-l` option in order to link an Objective-C or Objective-C++ program.

`-nostartfiles`
: Do not use the standard system startup files when linking. The standard system libraries are used normally, unless `-nostdlib`, `-nolibc`, or `-nodefaultlibs` is used.

`-nodefaultlibs`
: Do not use the standard system libraries when linking. Only the libraries you specify are passed to the linker, and options specifying linkage of the system libraries, such as `-static-libgcc` or `-shared-libgcc`, are ignored. The standard startup files are used normally, unless `-nostartfiles` is used.

The compiler may generate calls to `memcmp`, `memset`, `memcpy` and `memmove`. These entries are usually resolved by entries in libc. These entry points should be supplied through some other mechanism when this option is specified.

`-nolibc` Do not use the C library or system libraries tightly coupled with it when linking. Still link with the startup files, `libgcc` or toolchain provided language support libraries such as `libgnat`, `libgfortran` or `libstdc++` unless options preventing their inclusion are used as well. This typically removes `-lc` from the link command line, as well as system libraries that normally go with it and become meaningless when absence of a C library is assumed, for example `-lpthread` or `-lm` in some configurations. This is intended for bare-board targets when there is indeed no C library available.

`-nostdlib`
`--no-standard-libraries`
: Do not use the standard system startup files or libraries when linking. No startup files and only the libraries you specify are passed to the linker, and options specifying linkage of the system libraries, such as `-static-libgcc` or `-shared-libgcc`, are ignored.

The compiler may generate calls to `memcmp`, `memset`, `memcpy` and `memmove`. These entries are usually resolved by entries in libc. These entry points should be supplied through some other mechanism when this option is specified.

One of the standard libraries bypassed by `-nostdlib` and `-nodefaultlibs` is `libgcc.a`, a library of internal subroutines which GCC uses to overcome shortcomings of particular machines, or special needs for some languages. (See Section "Interfacing to GCC Output" in *GNU Compiler Collection (GCC) Internals*, for more discussion of `libgcc.a`.) In most cases, you need `libgcc.a` even when you want to avoid other standard libraries. In other words, when you specify `-nostdlib` or `-nodefaultlibs` you should usually specify `-lgcc` as well. This ensures that you have no unresolved references to internal GCC library subroutines. (An example of such an internal subroutine is `__main`, used to ensure C++ constructors are called; see Section "`collect2`" in *GNU Compiler Collection (GCC) Internals*.)

`-nostdlib++`
: Do not implicitly link with standard C++ libraries.

`-e` *entry*
`--entry=`*entry*
`--entry` *entry*
: Specify that the program entry point is *entry*. The argument is interpreted by the linker; the GNU linker accepts either a symbol name or an address.

`-pie`
`--pie` Produce a dynamically linked position independent executable on targets that support it. For predictable results, you must also specify the same set of options used for compilation (`-fpie`, `-fPIE`, or model suboptions) when you specify this linker option.

`-no-pie` Don't produce a dynamically linked position independent executable.

-static-pie
--static-pie
: Produce a static position independent executable on targets that support it. A static position independent executable is similar to a static executable, but can be loaded at any address without a dynamic linker. For predictable results, you must also specify the same set of options used for compilation (-fpie, -fPIE, or model suboptions) when you specify this linker option.

-pthread
: Link with the POSIX threads library. This option is supported on GNU/Linux targets, most other Unix derivatives, and also on x86 Cygwin and MinGW targets. On some targets this option also sets flags for the preprocessor, so it should be used consistently for both compilation and linking.

-r
: Produce a relocatable object as output. This is also known as partial linking.

-rdynamic
: Pass the flag -export-dynamic to the ELF linker, on targets that support it. This instructs the linker to add all symbols, not only used ones, to the dynamic symbol table. This option is needed for some uses of dlopen or to allow obtaining backtraces from within a program.

-s
: Remove all symbol table and relocation information from the executable.

-static
--static
: On systems that support dynamic linking, this overrides -pie and prevents linking with the shared libraries. On other systems, this option has no effect.

-shared
--shared
: Produce a shared object which can then be linked with other objects to form an executable. Not all systems support this option. For predictable results, you must also specify the same set of options used for compilation (-fpic, -fPIC, or model suboptions) when you specify this linker option.[1]

-shared-libgcc
-static-libgcc
: On systems that provide libgcc as a shared library, these options force the use of either the shared or static version, respectively. If no shared version of libgcc was built when the compiler was configured, these options have no effect.

There are several situations in which an application should use the shared libgcc instead of the static version. The most common of these is when the application wishes to throw and catch exceptions across different shared libraries. In that case, each of the libraries as well as the application itself should use the shared libgcc.

[1] On some systems, 'gcc -shared' needs to build supplementary stub code for constructors to work. On multi-libbed systems, 'gcc -shared' must select the correct support libraries to link against. Failing to supply the correct flags may lead to subtle defects. Supplying them in cases where they are not necessary is innocuous. -shared suppresses the addition of startup code to alter the floating-point environment as done with -ffast-math, -Ofast or -funsafe-math-optimizations on some targets.

Therefore, the G++ driver automatically adds `-shared-libgcc` whenever you build a shared library or a main executable, because C++ programs typically use exceptions, so this is the right thing to do.

If, instead, you use the GCC driver to create shared libraries, you may find that they are not always linked with the shared `libgcc`. If GCC finds, at its configuration time, that you have a non-GNU linker or a GNU linker that does not support option `--eh-frame-hdr`, it links the shared version of `libgcc` into shared libraries by default. Otherwise, it takes advantage of the linker and optimizes away the linking with the shared version of `libgcc`, linking with the static version of libgcc by default. This allows exceptions to propagate through such shared libraries, without incurring relocation costs at library load time.

However, if a library or main executable is supposed to throw or catch exceptions, you must link it using the G++ driver, or using the option `-shared-libgcc`, such that it is linked with the shared `libgcc`.

`-static-libasan`
: When the `-fsanitize=address` option is used to link a program, the GCC driver automatically links against `libasan`. If `libasan` is available as a shared library, and the `-static` option is not used, then this links against the shared version of `libasan`. The `-static-libasan` option directs the GCC driver to link `libasan` statically, without necessarily linking other libraries statically.

`-static-libtsan`
: When the `-fsanitize=thread` option is used to link a program, the GCC driver automatically links against `libtsan`. If `libtsan` is available as a shared library, and the `-static` option is not used, then this links against the shared version of `libtsan`. The `-static-libtsan` option directs the GCC driver to link `libtsan` statically, without necessarily linking other libraries statically.

`-static-liblsan`
: When the `-fsanitize=leak` option is used to link a program, the GCC driver automatically links against `liblsan`. If `liblsan` is available as a shared library, and the `-static` option is not used, then this links against the shared version of `liblsan`. The `-static-liblsan` option directs the GCC driver to link `liblsan` statically, without necessarily linking other libraries statically.

`-static-libubsan`
: When the `-fsanitize=undefined` option is used to link a program, the GCC driver automatically links against `libubsan`. If `libubsan` is available as a shared library, and the `-static` option is not used, then this links against the shared version of `libubsan`. The `-static-libubsan` option directs the GCC driver to link `libubsan` statically, without necessarily linking other libraries statically.

`-static-libstdc++`
: When the `g++` program is used to link a C++ program, it normally automatically links against `libstdc++`. If `libstdc++` is available as a shared library, and the `-static` option is not used, then this links against the shared version of `libstdc++`. That is normally fine. However, it is sometimes useful to freeze

the version of `libstdc++` used by the program without going all the way to a fully static link. The `-static-libstdc++` option directs the `g++` driver to link `libstdc++` statically, without necessarily linking other libraries statically.

`-symbolic`
`--symbolic`
: Bind references to global symbols when building a shared object. Warn about any unresolved references (unless overridden by the link editor option `-Xlinker -z -Xlinker defs`). Only a few systems support this option.

`-T` *`script`*
: Use *script* as the linker script. This option is supported by most systems using the GNU linker. On some targets, such as bare-board targets without an operating system, the `-T` option may be required when linking to avoid references to undefined symbols.

`-Xlinker` *`option`*
: Pass *option* as an option to the linker. You can use this to supply system-specific linker options that GCC does not recognize.

If you want to pass an option that takes a separate argument, you must use `-Xlinker` twice, once for the option and once for the argument. For example, to pass `-assert definitions`, you must write `-Xlinker -assert -Xlinker definitions`. It does not work to write `-Xlinker "-assert definitions"`, because this passes the entire string as a single argument, which is not what the linker expects.

When using the GNU linker, it is usually more convenient to pass arguments to linker options using the *`option`*`=`*`value`* syntax than as separate arguments. For example, you can specify `-Xlinker -Map=output.map` rather than `-Xlinker -Map -Xlinker output.map`. Other linkers may not support this syntax for command-line options.

`-Wl,`*`option`*
`--for-linker=`*`option`*
`--for-linker` *`option`*
: Pass *option* as an option to the linker. If *option* contains commas, it is split into multiple options at the commas. You can use this syntax to pass an argument to the option. For example, `-Wl,-Map,output.map` passes `-Map output.map` to the linker. When using the GNU linker, you can also get the same effect with `-Wl,-Map=output.map`.

`-u` *`symbol`*
`--force-link=`*`symbol`*
`--force-link` *`symbol`*
: Pretend the symbol *symbol* is undefined, to force linking of library modules to define it. You can use `-u` multiple times with different symbols to force loading of additional library modules.

`-Tbss=`*addr*
`-Tdata=`*addr*
`-Ttext=`*addr*
`-N`
`-n`
`-t`
`-Z`
`-z` *keyword*

These options are passed through to the linker without interpretation by GCC. Refer to your linker documentation for the meanings of these options.

3.17 Options for Directory Search

These options specify directories to search for header files, for libraries and for parts of the compiler:

`-I` *dir*
`-iquote` *dir*
`-isystem` *dir*
`-idirafter` *dir*
`--include-directory-after=`*dir*
`--include-directory-after` *dir*
`--include-directory=`*dir*
`--include-directory` *dir*

Add the directory *dir* to the list of directories to be searched for header files during preprocessing. `--include-directory` is an alias for `-I`, while `--include-directory-after` is an alias for `-idirafter`. If *dir* begins with '`=`' or `$SYSROOT`, then the '`=`' or `$SYSROOT` is replaced by the sysroot prefix; see `--sysroot` and `-isysroot`.

Directories specified with `-iquote` apply only to the quote form of the directive, `#include "`*file*`"`. Directories specified with `-I`, `-isystem`, or `-idirafter` apply to lookup for both the `#include "`*file*`"` and `#include <`*file*`>` directives.

You can specify any number or combination of these options on the command line to search for header files in several directories. The lookup order is as follows:

1. For the quote form of the include directive, the directory of the current file is searched first.
2. For the quote form of the include directive, the directories specified by `-iquote` options are searched in left-to-right order, as they appear on the command line.
3. Directories specified with `-I` options are scanned in left-to-right order.
4. Directories specified with `-isystem` options are scanned in left-to-right order.
5. Standard system directories are scanned.
6. Directories specified with `-idirafter` options are scanned in left-to-right order.

You can use `-I` to override a system header file, substituting your own version, since these directories are searched before the standard system header file directories. However, you should not use this option to add directories that contain vendor-supplied system header files; use `-isystem` for that.

The `-isystem` and `-idirafter` options also mark the directory as a system directory, so that it gets the same special treatment that is applied to the standard system directories.

If a standard system include directory, or a directory specified with `-isystem`, is also specified with `-I`, the `-I` option is ignored. The directory is still searched but as a system directory at its normal position in the system include chain. This is to ensure that GCC's procedure to fix buggy system headers and the ordering for the `#include_next` directive are not inadvertently changed. If you really need to change the search order for system directories, use the `-nostdinc` and/or `-isystem` options.

`-I-`
`--include-barrier`

Split the include path. This option has been deprecated. Please use `-iquote` instead for `-I` directories before the `-I-` and remove the `-I-` option.

Any directories specified with `-I` options before `-I-` are searched only for headers requested with `#include "`*`file`*`"`; they are not searched for `#include <`*`file`*`>`. If additional directories are specified with `-I` options after the `-I-`, those directories are searched for all '`#include`' directives.

In addition, `-I-` inhibits the use of the directory of the current file directory as the first search directory for `#include "`*`file`*`"`. There is no way to override this effect of `-I-`.

`-iprefix` *prefix*
`--include-prefix=`*prefix*
`--include-prefix` *prefix*

Specify *prefix* as the prefix for subsequent `-iwithprefix` options. If the prefix represents a directory, you should include the final '`/`'.

`-iwithprefix` *dir*
`-iwithprefixbefore` *dir*
`--include-with-prefix=`*prefix*
`--include-with-prefix` *prefix*
`--include-with-prefix-after=`*prefix*
`--include-with-prefix-after` *prefix*
`--include-with-prefix-before=`*prefix*
`--include-with-prefix-before` *prefix*

Append *dir* to the prefix specified previously with `-iprefix`, and add the resulting directory to the include search path. `-iwithprefixbefore` puts it in the same place `-I` would; `-iwithprefix` puts it where `-idirafter` would.

`--include-with-prefix` and `--include-with-prefix-after` are both aliases for `-iwithprefix`, while `--include-with-prefix-before` is an alias for `-iwithprefixbefore`.

`-isysroot dir`
: This option is like the `--sysroot` option, but applies only to header files (except for Darwin targets, where it applies to both header files and libraries). See the `--sysroot` option for more information.

`-imultilib dir`
: Use *dir* as a subdirectory of the directory containing target-specific C++ headers.

`-nostdinc`
`--no-standard-includes`
: Do not search the standard system directories for header files. Only the directories explicitly specified with `-I`, `-iquote`, `-isystem`, and/or `-idirafter` options (and the directory of the current file, if appropriate) are searched.

`-nostdinc++`
: Do not search for header files in the C++-specific standard directories, but do still search the other standard directories. (This option is used when building the C++ library.)

`--embed-dir=dir`
`--embed-directory=dir`
`--embed-directory dir`
: Append *dir* directory to the list of searched directories for `#embed` preprocessing directive or `__has_embed` macro. There are no default directories for `#embed`.

If *dir* begins with '`=`' or `$SYSROOT`, then the '`=`' or `$SYSROOT` is replaced by the sysroot prefix; see `--sysroot` and `-isysroot`.

`-iplugindir=dir`
: Set the directory to search for plugins that are passed by `-fplugin=name` instead of `-fplugin=path/name.so`. This option is not meant to be used by the user, but only passed by the driver.

`-Ldir`
`--library-directory=dir`
`--library-directory dir`
: Add directory *dir* to the list of directories to be searched for `-l`.

`-Bprefix`
`--prefix=prefix`
`--prefix prefix`
: This option specifies where to find the executables, libraries, include files, and data files of the compiler itself.

The compiler driver program runs one or more of the subprograms `cpp`, `cc1`, `as` and `ld`. It tries *prefix* as a prefix for each program it tries to run, both with and without '`machine/version/`' for the corresponding target machine and compiler version.

For each subprogram to be run, the compiler driver first tries the `-B` prefix, if any. If that name is not found, or if `-B` is not specified, the driver tries two standard prefixes, `/usr/lib/gcc/` and `/usr/local/lib/gcc/`. If neither of those results in a file name that is found, the unmodified program name is searched for using the directories specified in your `PATH` environment variable.

The compiler checks to see if the path provided by `-B` refers to a directory, and if necessary it adds a directory separator character at the end of the path.

`-B` prefixes that effectively specify directory names also apply to libraries in the linker, because the compiler translates these options into `-L` options for the linker. They also apply to include files in the preprocessor, because the compiler translates these options into `-isystem` options for the preprocessor. In this case, the compiler appends '`include`' to the prefix.

The runtime support file `libgcc.a` can also be searched for using the `-B` prefix, if needed. If it is not found there, the two standard prefixes above are tried, and that is all. The file is left out of the link if it is not found by those means.

Another way to specify a prefix much like the `-B` prefix is to use the environment variable `GCC_EXEC_PREFIX`. See Section 3.22 [Environment Variables], page 579.

As a special kludge, if the path provided by `-B` is `[dir/]stage`*N*`/`, where *N* is a number in the range 0 to 9, then it is replaced by `[dir/]include`. This is to help with boot-strapping the compiler.

`-no-canonical-prefixes`
`--no-canonical-prefixes`

Do not expand any symbolic links, resolve references to '`/../`' or '`/./`', or make the path absolute when generating a relative prefix.

`--sysroot=`*`dir`*
`--sysroot` *`dir`*

Use *dir* as the logical root directory for headers and libraries. For example, if the compiler normally searches for headers in `/usr/include` and libraries in `/usr/lib`, it instead searches *`dir`*`/usr/include` and *`dir`*`/usr/lib`.

If you use both this option and the `-isysroot` option, then the `--sysroot` option applies to libraries, but the `-isysroot` option applies to header files.

The GNU linker (beginning with version 2.16) has the necessary support for this option. If your linker does not support this option, the header file aspect of `--sysroot` still works, but the library aspect does not.

`--no-sysroot-suffix`

For some targets, a suffix is added to the root directory specified with `--sysroot`, depending on the other options used, so that headers may for example be found in *`dir`*`/`*`suffix`*`/usr/include` instead of *`dir`*`/usr/include`. This option disables the addition of such a suffix.

3.18 Options for Code Generation Conventions

These machine-independent options control the interface conventions used in code generation.

Most of them have both positive and negative forms; the negative form of `-ffoo` is `-fno-foo`. In the table below, only one of the forms is listed—the one that is not the default. You can figure out the other form by either removing '`no-`' or adding it.

`-fstack-reuse=`*`reuse-level`*

This option controls stack space reuse for user declared local/auto variables and compiler generated temporaries. *reuse_level* can be '`all`', '`named_vars`', or 'none'. 'all' enables stack reuse for all local variables and temporaries, 'named_vars' enables the reuse only for user defined local variables with names, and 'none' disables stack reuse completely. The default value is 'all'. The option is needed when the program extends the lifetime of a scoped local variable or a compiler generated temporary beyond the end point defined by the language. When a lifetime of a variable ends, and if the variable lives in memory, the optimizing compiler has the freedom to reuse its stack space with other temporaries or scoped local variables whose live range does not overlap with it. Legacy code extending local lifetime is likely to break with the stack reuse optimization.

For example,

```
int *p;
{
  int local1;

  p = &local1;
  local1 = 10;
  ....
}
{
   int local2;
   local2 = 20;
   ...
}

if (*p == 10)  // out of scope use of local1
  {

  }
```

Another example:

```
struct A
{
    A(int k) : i(k), j(k) { }
    int i;
    int j;
};

A *ap;

void foo(const A& ar)
{
   ap = &ar;
}

void bar()
{
   foo(A(10)); // temp object's lifetime ends when foo returns

   {
     A a(20);
     ....
   }
   ap->i+= 10;  // ap references out of scope temp whose space
                // is reused with a. What is the value of ap->i?
```

```
}
```

The lifetime of a compiler generated temporary is well defined by the C++ standard. When a lifetime of a temporary ends, and if the temporary lives in memory, the optimizing compiler has the freedom to reuse its stack space with other temporaries or scoped local variables whose live range does not overlap with it. However some of the legacy code relies on the behavior of older compilers in which temporaries' stack space is not reused, the aggressive stack reuse can lead to runtime errors. This option is used to control the temporary stack reuse optimization.

`-ftrapv` This option generates traps for signed overflow on addition, subtraction, multiplication operations. The options `-ftrapv` and `-fwrapv` override each other, so using `-ftrapv -fwrapv` on the command-line results in `-fwrapv` being effective. Note that only active options override, so using `-ftrapv -fwrapv -fno-wrapv` on the command-line results in `-ftrapv` being effective.

`-fwrapv` This option instructs the compiler to assume that signed arithmetic overflow of addition, subtraction and multiplication wraps around using twos-complement representation. This flag enables some optimizations and disables others. The options `-ftrapv` and `-fwrapv` override each other, so using `-ftrapv -fwrapv` on the command-line results in `-fwrapv` being effective. Note that only active options override, so using `-ftrapv -fwrapv -fno-wrapv` on the command-line results in `-ftrapv` being effective.

`-fwrapv-pointer`

This option instructs the compiler to assume that pointer arithmetic overflow on addition and subtraction wraps around using twos-complement representation. This flag disables some optimizations which assume pointer overflow is invalid.

`-fstrict-overflow`

This option implies `-fno-wrapv -fno-wrapv-pointer` and when negated implies `-fwrapv -fwrapv-pointer`.

`-fexceptions`

Enable exception handling. Generates extra code needed to propagate exceptions. For some targets, this implies GCC generates frame unwind information for all functions, which can produce significant data size overhead, although it does not affect execution. If you do not specify this option, GCC enables it by default for languages like C++ that normally require exception handling, and disables it for languages like C that do not normally require it. However, you may need to enable this option when compiling C code that needs to interoperate properly with exception handlers written in C++. You may also wish to disable this option if you are compiling older C++ programs that don't use exception handling.

`-fnon-call-exceptions`

Generate code that allows trapping instructions to throw exceptions. Note that this requires platform-specific runtime support that does not exist everywhere. Moreover, it only allows *trapping* instructions to throw exceptions, i.e.

memory references or floating-point instructions. It does not allow exceptions to be thrown from arbitrary signal handlers such as `SIGALRM`. This enables `-fexceptions`.

`-fdelete-dead-exceptions`
: Consider that instructions that may throw exceptions but don't otherwise contribute to the execution of the program can be optimized away. This does not affect calls to functions except those with the `pure` or `const` attributes. This option is enabled by default for the Ada and C++ compilers, as permitted by the language specifications. Optimization passes that cause dead exceptions to be removed are enabled independently at different optimization levels.

`-funwind-tables`
: Similar to `-fexceptions`, except that it just generates any needed static data, but does not affect the generated code in any other way. You normally do not need to enable this option; instead, a language processor that needs this handling enables it on your behalf.

`-fasynchronous-unwind-tables`
: Generate unwind table in DWARF format, if supported by target machine. The table is exact at each instruction boundary, so it can be used for stack unwinding from asynchronous events (such as debugger or garbage collector).

`-fno-gnu-unique`
: On systems with recent GNU assembler and C library, the C++ compiler uses the `STB_GNU_UNIQUE` binding to make sure that definitions of template static data members and static local variables in inline functions are unique even in the presence of `RTLD_LOCAL`; this is necessary to avoid problems with a library used by two different `RTLD_LOCAL` plugins depending on a definition in one of them and therefore disagreeing with the other one about the binding of the symbol. But this causes `dlclose` to be ignored for affected DSOs; if your program relies on reinitialization of a DSO via `dlclose` and `dlopen`, you can use `-fno-gnu-unique`.

`-fpcc-struct-return`
: Return "short" `struct` and `union` values in memory like longer ones, rather than in registers. This convention is less efficient, but it has the advantage of allowing intercallability between GCC-compiled files and files compiled with other compilers, particularly the Portable C Compiler (pcc).

  The precise convention for returning structures in memory depends on the target configuration macros.

  Short structures and unions are those whose size and alignment match that of some integer type.

  Warning: code compiled with the `-fpcc-struct-return` switch is not binary compatible with code compiled with the `-freg-struct-return` switch. Use it to conform to a non-default application binary interface.

`-freg-struct-return`
: Return `struct` and `union` values in registers when possible. This is more efficient for small structures than `-fpcc-struct-return`.

If you specify neither `-fpcc-struct-return` nor `-freg-struct-return`, GCC defaults to whichever convention is standard for the target. If there is no standard convention, GCC defaults to `-fpcc-struct-return`, except on targets where GCC is the principal compiler. In those cases, we can choose the standard, and we chose the more efficient register return alternative.

Warning: code compiled with the `-freg-struct-return` switch is not binary compatible with code compiled with the `-fpcc-struct-return` switch. Use it to conform to a non-default application binary interface.

`-fshort-enums`
: Allocate to an `enum` type only as many bytes as it needs for the declared range of possible values. Specifically, the `enum` type is equivalent to the smallest integer type that has enough room. This option has no effect for an enumeration type with a fixed underlying type.

Warning: the `-fshort-enums` switch causes GCC to generate code that is not binary compatible with code generated without that switch. Use it to conform to a non-default application binary interface.

`-fshort-wchar`
: Override the underlying type for `wchar_t` to be `short unsigned int` instead of the default for the target. This option is useful for building programs to run under WINE.

Warning: the `-fshort-wchar` switch causes GCC to generate code that is not binary compatible with code generated without that switch. Use it to conform to a non-default application binary interface.

`-fcommon`
: In C code, this option controls the placement of global variables defined without an initializer, known as *tentative definitions* in the C standard. Tentative definitions are distinct from declarations of a variable with the `extern` keyword, which do not allocate storage.

The default is `-fno-common`, which specifies that the compiler places uninitialized global variables in the BSS section of the object file. This inhibits the merging of tentative definitions by the linker so you get a multiple-definition error if the same variable is accidentally defined in more than one compilation unit.

The `-fcommon` places uninitialized global variables in a common block. This allows the linker to resolve all tentative definitions of the same variable in different compilation units to the same object, or to a non-tentative definition. This behavior is inconsistent with C++, and on many targets implies a speed and code size penalty on global variable references. It is mainly useful to enable legacy code to link without errors.

`-fno-ident`
`-Qy`
`-Qn`
: `-fno-ident` suppresses emission of `.ident` assembler directives and causes the `#ident` preprocessor directive to be ignored. `-Qy` and `-Qn` are obsolete synonyms for `-fident` and `-fno-ident`, respectively.

`-finhibit-size-directive`

Don't output a `.size` assembler directive, or anything else that would cause trouble if the function is split in the middle, and the two halves are placed at locations far apart in memory. This option is used when compiling `crtstuff.c`; you should not need to use it for anything else.

`-fverbose-asm`

Put extra commentary information in the generated assembly code to make it more readable. This option is generally only of use to those who actually need to read the generated assembly code (perhaps while debugging the compiler itself).

`-fno-verbose-asm`, the default, causes the extra information to be omitted and is useful when comparing two assembler files.

The added comments include:

- information on the compiler version and command-line options,
- the source code lines associated with the assembly instructions, in the form FILENAME:LINENUMBER:CONTENT OF LINE,
- hints on which high-level expressions correspond to the various assembly instruction operands.

For example, given this C source file:

```
int test (int n)
{
  int i;
  int total = 0;

  for (i = 0; i < n; i++)
    total += i * i;

  return total;
}
```

compiling to (x86_64) assembly via `-S` and emitting the result direct to stdout via `-o -`

```
gcc -S test.c -fverbose-asm -Os -o -
```

gives output similar to this:

```
.file "test.c"
# GNU C11 (GCC) version 7.0.0 20160809 (experimental) (x86_64-pc-linux-gnu)
  [...snip...]
# options passed:
  [...snip...]

.text
.globl test
.type test, @function
test:
.LFB0:
.cfi_startproc
# test.c:4:   int total = 0;
xorl %eax, %eax # <retval>
# test.c:6:   for (i = 0; i < n; i++)
xorl %edx, %edx # i
```

```
.L2:
# test.c:6:   for (i = 0; i < n; i++)
cmpl %edi, %edx # n, i
jge .L5 #,
# test.c:7:     total += i * i;
movl %edx, %ecx # i, tmp92
imull %edx, %ecx # i, tmp92
# test.c:6:   for (i = 0; i < n; i++)
incl %edx # i
# test.c:7:     total += i * i;
addl %ecx, %eax # tmp92, <retval>
jmp .L2 #
.L5:
# test.c:10: }
ret
.cfi_endproc
.LFE0:
.size test, .-test
.ident "GCC: (GNU) 7.0.0 20160809 (experimental)"
.section .note.GNU-stack,"",@progbits
```

The comments are intended for humans rather than machines and hence the precise format of the comments is subject to change.

`-frecord-gcc-switches`
: This switch causes the command line used to invoke the compiler to be recorded into the object file that is being created. This switch is only implemented on some targets and the exact format of the recording is target and binary file format dependent, but it usually takes the form of a section containing ASCII text. This switch is related to the `-fverbose-asm` switch, but that switch only records information in the assembler output file as comments, so it never reaches the object file. See also `-grecord-gcc-switches` for another way of storing compiler options into the object file.

`-fpic`
: Generate position-independent code (PIC) suitable for use in a shared library, if supported for the target machine. Such code accesses all constant addresses through a global offset table (GOT). The dynamic loader resolves the GOT entries when the program starts (the dynamic loader is not part of GCC; it is part of the operating system). If the GOT size for the linked executable exceeds a machine-specific maximum size, you get an error message from the linker indicating that `-fpic` does not work; in that case, recompile with `-fPIC` instead. (These maximums are 8k on the SPARC, 28k on AArch64 and 32k on the m68k and RS/6000. The x86 has no such limit.)

  Position-independent code requires special support, and therefore works only on certain machines. For the x86, GCC supports PIC for System V but not for the Sun 386i. Code generated for the IBM RS/6000 is always position-independent.

  When this flag is set, the macros `__pic__` and `__PIC__` are defined to 1.

`-fPIC`
: If supported for the target machine, emit position-independent code, suitable for dynamic linking and avoiding any limit on the size of the global offset table. This option makes a difference on AArch64, m68k, PowerPC and SPARC.

  Position-independent code requires special support, and therefore works only on certain machines.

When this flag is set, the macros `__pic__` and `__PIC__` are defined to 2.

`-fpie`
`-fPIE` These options are similar to `-fpic` and `-fPIC`, but the generated position-independent code can be only linked into executables. Usually these options are used to compile code that will be linked using the `-pie` GCC option.

`-fpie` and `-fPIE` both define the macros `__pie__` and `__PIE__`. The macros have the value 1 for `-fpie` and 2 for `-fPIE`.

`-fno-plt` Do not use the PLT for external function calls in position-independent code. Instead, load the callee address at call sites from the GOT and branch to it. This leads to more efficient code by eliminating PLT stubs and exposing GOT loads to optimizations. On architectures such as 32-bit x86 where PLT stubs expect the GOT pointer in a specific register, this gives more register allocation freedom to the compiler. Lazy binding requires use of the PLT; with `-fno-plt` all external symbols are resolved at load time.

Alternatively, the function attribute `noplt` can be used to avoid calls through the PLT for specific external functions.

In position-dependent code, a few targets also convert calls to functions that are marked to not use the PLT to use the GOT instead.

`-fno-jump-tables`
Do not use jump tables for switch statements even where it would be more efficient than other code generation strategies. This option is of use in conjunction with `-fpic` or `-fPIC` for building code that forms part of a dynamic linker and cannot reference the address of a jump table. On some targets, jump tables do not require a GOT and this option is not needed.

`-fno-bit-tests`
Do not use bit tests for switch statements even where it would be more efficient than other code generation strategies.

`-ffixed-`*reg*
Treat the register named *reg* as a fixed register; generated code should never refer to it (except perhaps as a stack pointer, frame pointer or in some other fixed role).

reg must be the name of a register. The register names accepted are machine-specific and are defined in the `REGISTER_NAMES` macro in the machine description macro file.

This flag does not have a negative form, because it specifies a three-way choice.

`-fcall-used-`*reg*
Treat the register named *reg* as an allocable register that is clobbered by function calls. It may be allocated for temporaries or variables that do not live across a call. Functions compiled this way do not save and restore the register *reg*.

It is an error to use this flag with the frame pointer or stack pointer. Use of this flag for other registers that have fixed pervasive roles in the machine's execution model produces disastrous results.

This flag does not have a negative form, because it specifies a three-way choice.

`-fcall-saved-`*reg*
: Treat the register named *reg* as an allocable register saved by functions. It may be allocated even for temporaries or variables that live across a call. Functions compiled this way save and restore the register *reg* if they use it.

  It is an error to use this flag with the frame pointer or stack pointer. Use of this flag for other registers that have fixed pervasive roles in the machine's execution model produces disastrous results.

  A different sort of disaster results from the use of this flag for a register in which function values may be returned.

  This flag does not have a negative form, because it specifies a three-way choice.

`-fpack-struct[=`*n*`]`
: Without a value specified, pack all structure members together without holes. When a value is specified (which must be a small power of two), pack structure members according to this value, representing the maximum alignment (that is, objects with default alignment requirements larger than this are output potentially unaligned at the next fitting location.

  Warning: the `-fpack-struct` switch causes GCC to generate code that is not binary compatible with code generated without that switch. Additionally, it makes the code suboptimal. Use it to conform to a non-default application binary interface.

`-fleading-underscore`
: This option and its counterpart, `-fno-leading-underscore`, forcibly change the way C symbols are represented in the object file. One use is to help link with legacy assembly code.

  Warning: the `-fleading-underscore` switch causes GCC to generate code that is not binary compatible with code generated without that switch. Use it to conform to a non-default application binary interface. Not all targets provide complete support for this switch.

`-ftls-model=`*model*
: Alter the thread-local storage model to be used (see Section 6.6 [Thread-Local], page 746). The *model* argument should be one of '`global-dynamic`', '`local-dynamic`', '`initial-exec`' or '`local-exec`'. Note that the choice is subject to optimization: the compiler may use a more efficient model for symbols not visible outside of the translation unit, or if `-fpic` is not given on the command line.

  The default without `-fpic` is '`initial-exec`'; with `-fpic` the default is '`global-dynamic`'.

`-ftrampolines`
: For targets that normally need trampolines for nested functions, always generate them instead of using descriptors. Otherwise, for targets that do not need them, like for example HP-PA or IA-64, do nothing.

  A trampoline is a small piece of code that is created at run time on the stack when the address of a nested function is taken, and is used to call the nested function indirectly. Therefore, it requires the stack to be made executable in order for the program to work properly.

`-fno-trampolines` is enabled by default on a language by language basis to let the compiler avoid generating them, if it computes that this is safe, and replace them with descriptors. Descriptors are made up of data only, but the generated code must be prepared to deal with them. As of this writing, `-fno-trampolines` is enabled by default only for Ada.

Moreover, code compiled with `-ftrampolines` and code compiled with `-fno-trampolines` are not binary compatible if nested functions are present. This option must therefore be used on a program-wide basis and be manipulated with extreme care.

For languages other than Ada, the `-ftrampolines` and `-fno-trampolines` options currently have no effect, and trampolines are always generated on platforms that need them for nested functions.

`-ftrampoline-impl=`[`stack|heap`]

By default, trampolines are generated on stack. However, certain platforms (such as the Apple M1) do not permit an executable stack. Compiling with `-ftrampoline-impl=heap` generate calls to `__gcc_nested_func_ptr_created` and `__gcc_nested_func_ptr_deleted` in order to allocate and deallocate trampoline space on the executable heap. These functions are implemented in libgcc, and will only be provided on specific targets: x86_64 Darwin, x86_64 and aarch64 Linux. *PLEASE NOTE*: Heap trampolines are *not* guaranteed to be correctly deallocated if you `setjmp`, instantiate nested functions, and then `longjmp` back to a state prior to having allocated those nested functions.

`-fvisibility=`[`default|internal|hidden|protected`]

Set the default ELF image symbol visibility to the specified option—all symbols are marked with this unless overridden within the code. Using this feature can very substantially improve linking and load times of shared object libraries, produce more optimized code, provide near-perfect API export and prevent symbol clashes. It is **strongly** recommended that you use this in any shared objects you distribute.

Despite the nomenclature, '`default`' always means public; i.e., available to be linked against from outside the shared object. '`protected`' and '`internal`' are pretty useless in real-world usage so the only other commonly used option is '`hidden`'. The default if `-fvisibility` isn't specified is '`default`', i.e., make every symbol public.

A good explanation of the benefits offered by ensuring ELF symbols have the correct visibility is given by "How To Write Shared Libraries" by Ulrich Drepper (which can be found at `https://www.akkadia.org/drepper/`)—however a superior solution made possible by this option to marking things hidden when the default is public is to make the default hidden and mark things public. This is the norm with DLLs on Windows and with `-fvisibility=hidden` and `__attribute__ ((visibility("default")))` instead of `__declspec(dllexport)` you get almost identical semantics with identical syntax. This is a great boon to those working with cross-platform projects.

For those adding visibility support to existing code, you may find `#pragma GCC visibility` of use. This works by you enclosing the declarations you wish to set visibility for with (for example) `#pragma GCC visibility push(hidden)` and `#pragma GCC visibility pop`. Bear in mind that symbol visibility should be viewed **as part of the API interface contract** and thus all new code should always specify visibility when it is not the default; i.e., declarations only for use within the local DSO should **always** be marked explicitly as hidden as so to avoid PLT indirection overheads—making this abundantly clear also aids readability and self-documentation of the code. Note that due to ISO C++ specification requirements, `operator new` and `operator delete` must always be of default visibility.

Be aware that headers from outside your project, in particular system headers and headers from any other library you use, may not be expecting to be compiled with visibility other than the default. You may need to explicitly say `#pragma GCC visibility push(default)` before including any such headers.

`extern` declarations are not affected by `-fvisibility`, so a lot of code can be recompiled with `-fvisibility=hidden` with no modifications. However, this means that calls to `extern` functions with no explicit visibility use the PLT, so it is more effective to use `__attribute ((visibility))` and/or `#pragma GCC visibility` to tell the compiler which `extern` declarations should be treated as hidden.

Note that `-fvisibility` does affect C++ vague linkage entities. This means that, for instance, an exception class that is be thrown between DSOs must be explicitly marked with default visibility so that the '`type_info`' nodes are unified between the DSOs.

An overview of these techniques, their benefits and how to use them is at `https://gcc.gnu.org/wiki/Visibility`.

`-fstrict-volatile-bitfields`

This option should be used if accesses to volatile bit-fields (or other structure fields, although the compiler usually honors those types anyway) should use a single access of the width of the field's type, aligned to a natural alignment if possible. For example, targets with memory-mapped peripheral registers might require all such accesses to be 16 bits wide; with this flag you can declare all peripheral bit-fields as `unsigned short` (assuming short is 16 bits on these targets) to force GCC to use 16-bit accesses instead of, perhaps, a more efficient 32-bit access.

If this option is disabled, the compiler uses the most efficient instruction. In the previous example, that might be a 32-bit load instruction, even though that accesses bytes that do not contain any portion of the bit-field, or memory-mapped registers unrelated to the one being updated.

In some cases, such as when the `packed` attribute is applied to a structure field, it may not be possible to access the field with a single read or write that is correctly aligned for the target machine. In this case GCC falls back to generating multiple accesses rather than code that will fault or truncate the result at run time.

Note: Due to restrictions of the C/C++11 memory model, write accesses are not allowed to touch non bit-field members. It is therefore recommended to define all bits of the field's type as bit-field members.

The default value of this option is determined by the application binary interface for the target processor.

`-fsync-libcalls`

This option controls whether any out-of-line instance of the `__sync` family of functions may be used to implement the C++11 `__atomic` family of functions.

The default value of this option is enabled, thus the only useful form of the option is `-fno-sync-libcalls`. This option is used in the implementation of the `libatomic` runtime library.

`-fzero-init-padding-bits=`*value*

Guarantee zero initialization of padding bits in automatic variable initializers. Certain languages guarantee zero initialization of padding bits in certain cases, e.g. C23 when using empty initializers (`{}`), or C++ when using zero-initialization or C guarantees that fields not specified in an initializer have their padding bits zero initialized. This option allows to change when padding bits in initializers are guaranteed to be zero initialized. The default is `-fzero-init-padding-bits=standard`, which makes no further guarantees than the corresponding standard. E.g.

```
struct A { char a; unsigned long long b; char c; };
union B { char a; unsigned long long b; };
struct A a = {}; // C23 guarantees padding bits are zero.
struct A b = { 1, 2, 3 }; // No guarantees.
union B c = {}; // C23 guarantees padding bits are zero.
union B d = { 1 }; // No guarantees.
```

`-fzero-init-padding-bits=unions` guarantees zero initialization of padding bits in unions on top of what the standards guarantee, if the initializer of an union is empty (then all bits of the union are zero initialized) or if the initialized member of the union is smaller than the size of the union (in that case guarantees padding bits outside of the initialized member to be zero initialized). This was the GCC behavior before GCC 15 and in the above example guarantees zero initialization of last `sizeof (unsigned long long) - 1` bytes in the union.

`-fzero-init-padding-bits=all` guarantees additionally zero initialization of padding bits of other aggregates, so the padding in between `b.a` and `b.b` (if any) and tail padding in the structure (if any).

3.19 GCC Developer Options

This section describes command-line options that are primarily of interest to GCC developers, including options to support compiler testing and investigation of compiler bugs and compile-time performance problems. This includes options that produce debug dumps at various points in the compilation; that print statistics such as memory use and execution time; and that print information about GCC's configuration, such as where it searches for libraries. You should rarely need to use any of these options for ordinary compilation and linking tasks.

Many developer options that cause GCC to dump output to a file take an optional '=*filename*' suffix. You can specify 'stdout' or '-' to dump to standard output, and 'stderr' for standard error.

If '=*filename*' is omitted, a default dump file name is constructed by concatenating the base dump file name, a pass number, phase letter, and pass name. The base dump file name is the name of output file produced by the compiler if explicitly specified and not an executable; otherwise it is the source file name. The pass number is determined by the order passes are registered with the compiler's pass manager. This is generally the same as the order of execution, but passes registered by plugins, target-specific passes, or passes that are otherwise registered late are numbered higher than the pass named 'final', even if they are executed earlier. The phase letter is one of 'i' (inter-procedural analysis), 'l' (language-specific), 'r' (RTL), or 't' (tree). The files are created in the directory of the output file.

-fcallgraph-info
-fcallgraph-info=*MARKERS*

Makes the compiler output callgraph information for the program, on a per-object-file basis. The information is generated in the common VCG format. It can be decorated with additional, per-node and/or per-edge information, if a list of comma-separated markers is additionally specified. When the su marker is specified, the callgraph is decorated with stack usage information; it is equivalent to -fstack-usage. When the da marker is specified, the callgraph is decorated with information about dynamically allocated objects.

When compiling with -flto, no callgraph information is output along with the object file. At LTO link time, -fcallgraph-info may generate multiple callgraph information files next to intermediate LTO output files.

-d*letters*
--dump=*letters*
--dump *letters*
-fdump-rtl-*pass*
-fdump-rtl-*pass*-*options*
-fdump-rtl-*pass*-*options*=*filename*

Says to make debugging dumps during compilation at times specified by *letters* when using -d or by *pass* when using -fdump-rtl. This is used for debugging the RTL-based passes of the compiler.

Some -d*letters* switches have different meaning when -E is used for preprocessing. See Section 3.14 [Preprocessor Options], page 297, for information about preprocessor-specific dump options.

The '-*options*' form allows greater control over the details of the dump. See -fdump-tree.

Here are actual instances of command-line options following these patterns and their meanings:

-fdump-rtl-alignments

Dump after branch alignments have been computed.

`-fdump-rtl-asmcons`
: Dump after fixing rtl statements that have unsatisfied in/out constraints.

`-fdump-rtl-auto_inc_dec`
: Dump after auto-inc-dec discovery. This pass is only run on architectures that have auto inc or auto dec instructions.

`-fdump-rtl-barriers`
: Dump after cleaning up the barrier instructions.

`-fdump-rtl-bbpart`
: Dump after partitioning hot and cold basic blocks.

`-fdump-rtl-bbro`
: Dump after block reordering.

`-fdump-rtl-btl1`
`-fdump-rtl-btl2`
: `-fdump-rtl-btl1` and `-fdump-rtl-btl2` enable dumping after the two branch target load optimization passes.

`-fdump-rtl-bypass`
: Dump after jump bypassing and control flow optimizations.

`-fdump-rtl-combine`
: Dump after the RTL instruction combination pass.

`-fdump-rtl-compgotos`
: Dump after duplicating the computed gotos.

`-fdump-rtl-ce1`
`-fdump-rtl-ce2`
`-fdump-rtl-ce3`
: `-fdump-rtl-ce1`, `-fdump-rtl-ce2`, and `-fdump-rtl-ce3` enable dumping after the three if conversion passes.

`-fdump-rtl-cprop_hardreg`
: Dump after hard register copy propagation.

`-fdump-rtl-csa`
: Dump after combining stack adjustments.

`-fdump-rtl-cse1`
`-fdump-rtl-cse2`
: `-fdump-rtl-cse1` and `-fdump-rtl-cse2` enable dumping after the two common subexpression elimination passes.

`-fdump-rtl-dce`
: Dump after the standalone dead code elimination passes.

`-fdump-rtl-dbr`
: Dump after delayed branch scheduling.

`-fdump-rtl-dce1`
`-fdump-rtl-dce2`
: `-fdump-rtl-dce1` and `-fdump-rtl-dce2` enable dumping after the two dead store elimination passes.

`-fdump-rtl-eh`
: Dump after finalization of EH handling code.

`-fdump-rtl-eh_ranges`
: Dump after conversion of EH handling range regions.

`-fdump-rtl-expand`
: Dump after RTL generation.

`-fdump-rtl-fwprop1`
`-fdump-rtl-fwprop2`
: `-fdump-rtl-fwprop1` and `-fdump-rtl-fwprop2` enable dumping after the two forward propagation passes.

`-fdump-rtl-gcse1`
`-fdump-rtl-gcse2`
: `-fdump-rtl-gcse1` and `-fdump-rtl-gcse2` enable dumping after global common subexpression elimination.

`-fdump-rtl-init-regs`
: Dump after the initialization of the registers.

`-fdump-rtl-initvals`
: Dump after the computation of the initial value sets.

`-fdump-rtl-into_cfglayout`
: Dump after converting to cfglayout mode.

`-fdump-rtl-ira`
: Dump after iterated register allocation.

`-fdump-rtl-jump`
: Dump after the second jump optimization.

`-fdump-rtl-loop2`
: `-fdump-rtl-loop2` enables dumping after the rtl loop optimization passes.

`-fdump-rtl-mach`
: Dump after performing the machine dependent reorganization pass, if that pass exists.

`-fdump-rtl-mode_sw`
: Dump after removing redundant mode switches.

`-fdump-rtl-rnreg`
: Dump after register renumbering.

`-fdump-rtl-outof_cfglayout`
: Dump after converting from cfglayout mode.

`-fdump-rtl-peephole2`
: Dump after the peephole pass.

`-fdump-rtl-postreload`
: Dump after post-reload optimizations.

`-fdump-rtl-pro_and_epilogue`
: Dump after generating the function prologues and epilogues.

`-fdump-rtl-sched1`
`-fdump-rtl-sched2`
: `-fdump-rtl-sched1` and `-fdump-rtl-sched2` enable dumping after the basic block scheduling passes.

`-fdump-rtl-ree`
: Dump after sign/zero extension elimination.

`-fdump-rtl-seqabstr`
: Dump after common sequence discovery.

`-fdump-rtl-shorten`
: Dump after shortening branches.

`-fdump-rtl-split1`
`-fdump-rtl-split2`
`-fdump-rtl-split3`
`-fdump-rtl-split4`
`-fdump-rtl-split5`
: These options enable dumping after five rounds of instruction splitting.

`-fdump-rtl-sms`
: Dump after modulo scheduling. This pass is only run on some architectures.

`-fdump-rtl-stack`
: Dump after conversion from GCC's "flat register file" registers to the x87's stack-like registers. This pass is only run on x86 variants.

`-fdump-rtl-subreg1`
`-fdump-rtl-subreg2`
: `-fdump-rtl-subreg1` and `-fdump-rtl-subreg2` enable dumping after the two subreg expansion passes.

`-fdump-rtl-vartrack`
: Dump after variable tracking.

`-fdump-rtl-vregs`
: Dump after converting virtual registers to hard registers.

`-fdump-rtl-web`
: Dump after live range splitting.

`-fdump-rtl-regclass`
`-fdump-rtl-subregs_of_mode_init`
`-fdump-rtl-subregs_of_mode_finish`
`-fdump-rtl-dfinit`
`-fdump-rtl-dfinish`
These dumps are defined but always produce empty files.

`-da`
`--dump=a`
`-fdump-rtl-all`
Produce all the dumps listed above.

`-dA`
`--dump=A` Annotate the assembler output with miscellaneous debugging information.

`-dD`
`--dump=D` Dump all macro definitions, at the end of preprocessing, in addition to normal output.

`-dH`
`--dump=H` Produce a core dump whenever an error occurs.

`-dp`
`--dump=p` Annotate the assembler output with a comment indicating which pattern and alternative is used. The length and cost of each instruction are also printed.

`-dP`
`--dump=P` Dump the RTL in the assembler output as a comment before each instruction. Also turns on `-dp` annotation.

`-dx`
`--dump=x` Just generate RTL for a function instead of compiling it. Usually used with `-fdump-rtl-expand`.

`-fdump-debug`
Dump debugging information generated during the debug generation phase.

`-fdump-earlydebug`
Dump debugging information generated during the early debug generation phase.

`-fdump-noaddr`
When doing debugging dumps, suppress address output. This makes it more feasible to use diff on debugging dumps for compiler invocations with different compiler binaries and/or different text / bss / data / heap / stack / dso start locations.

`-freport-bug`
Collect and dump debug information into a temporary file if an internal compiler error (ICE) occurs.

`-fdump-unnumbered`
When doing debugging dumps, suppress instruction numbers and address output. This makes it more feasible to use diff on debugging dumps for compiler invocations with different options, in particular with and without `-g`.

`-fdump-unnumbered-links`
When doing debugging dumps (see `-d` option above), suppress instruction numbers for the links to the previous and next instructions in a sequence.

`-fdump-internal-locations`
Dump detailed information about GCC's internal representation of source code locations.

`-fdump-ipa-`*`switch`*
`-fdump-ipa-`*`switch-options`*
Control the dumping at various stages of inter-procedural analysis language tree to a file. The file name is generated by appending a switch specific suffix to the source file name, and the file is created in the same directory as the output file. The following dumps are possible:

'`all`' Enables all inter-procedural analysis dumps.

'`cgraph`' Dumps information about call-graph optimization, unused function removal, and inlining decisions.

'`inline`' Dump after function inlining.

'`strubm`' Dump after selecting `strub` modes, and recording the selections as function attributes.

'`strub`' Dump `strub` transformations: interface changes, function wrapping, and insertion of builtin calls for stack scrubbing and watermarking.

Additionally, the options `-optimized`, `-missed`, `-note`, and `-all` can be provided, with the same meaning as for `-fopt-info`, defaulting to `-optimized`.

For example, `-fdump-ipa-inline-optimized-missed` will emit information on callsites that were inlined, along with callsites that were not inlined.

By default, the dump will contain messages about successful optimizations (equivalent to `-optimized`) together with low-level details about the analysis.

`-fdump-ipa-clones`
Create a dump file containing information about creation of call graph node clones and removals of call graph nodes during inter-procedural optimizations and transformations. Its main intended use is that tools that create live-patches can determine the set of functions that need to be live-patched to completely replace a particular function (see `-flive-patching`). The file name is generated by appending suffix `ipa-clones` to the source file name, and the file is created in the same directory as the output file. Each entry in the file is on a separate line containing semicolon separated fields.

In the case of call graph clone creation, the individual fields are:

1. String `Callgraph clone`.

2. Name of the function being cloned as it is presented to the assembler.
3. A number that uniquely represents the function being cloned in the call graph. Note that the number is unique only within a compilation unit or within whole-program analysis but is likely to be different in the two phases.
4. The file name of the source file where the function is defined.
5. The line on which the function definition is located.
6. The column where the function definition is located.
7. Name of the new function clone as it is presented to the assembler.
8. A number that uniquely represents the new function clone in the call graph. Note that the number is unique only within a compilation unit or within whole-program analysis but is likely to be different in the two phases.
9. The file name of the source file where the source code location of the new clone points to.
10. The line to which the source code location of the new clone points to.
11. The column to which the source code location of the new clone points to.
12. A string that determines the reason for cloning.

In the case of call graph clone removal, the individual fields are:

1. String `Callgraph removal`.
2. Name of the function being removed as it would be presented to the assembler.
3. A number that uniquely represents the function being cloned in the call graph. Note that the number is unique only within a compilation unit or within whole-program analysis but is likely to be different in the two phases.
4. The file name of the source file where the function is defined.
5. The line on which the function definition is located.
6. The column where the function definition is located.

`-fdump-lang`
: Dump language-specific information. The file name is made by appending `.lang` to the source file name.

`-fdump-lang-all`
`-fdump-lang-`*`switch`*
`-fdump-lang-`*`switch-options`*
`-fdump-lang-`*`switch-options=filename`*
: Control the dumping of language-specific information. The *options* and *filename* portions behave as described in the `-fdump-tree` option. `-fdump-tree-all` enables all language-specific dumps; other options vary with the language. For instance, see See Section 3.5 [C++ Dialect Options], page 52, for the `-fdump-lang` flags supported by the C++ front-end.

`-fdump-passes`
: Print on `stderr` the list of optimization passes that are turned on and off by the current command-line options.

`-fdump-statistics-`*option*
: Enable and control dumping of pass statistics in a separate file. The file name is generated by appending a suffix ending in '`.statistics`' to the source file name, and the file is created in the same directory as the output file. If the '`-`*option*' form is used, '`-stats`' causes counters to be summed over the whole compilation unit while '`-details`' dumps every event as the passes generate them. The default with no option is to sum counters for each function compiled.

`-fdump-tree-all`
`-fdump-tree-`*switch*
`-fdump-tree-`*switch*`-`*options*
`-fdump-tree-`*switch*`-`*options*`=`*filename*
: Control the dumping at various stages of processing the intermediate language tree to a file. If the '`-`*options*' form is used, *options* is a list of '`-`' separated options which control the details of the dump. Not all options are applicable to all dumps; those that are not meaningful are ignored. The following options are available

'`address`' Print the address of each node. Usually this is not meaningful as it changes according to the environment and source file. Its primary use is for tying up a dump file with a debug environment.

'`asmname`' If `DECL_ASSEMBLER_NAME` has been set for a given decl, use that in the dump instead of `DECL_NAME`. Its primary use is ease of use working backward from mangled names in the assembly file.

'`slim`' When dumping front-end intermediate representations, inhibit dumping of members of a scope or body of a function merely because that scope has been reached. Only dump such items when they are directly reachable by some other path.

When dumping pretty-printed trees, this option inhibits dumping the bodies of control structures.

When dumping RTL, print the RTL in slim (condensed) form instead of the default LISP-like representation.

'`raw`' Print a raw representation of the tree. By default, trees are pretty-printed into a C-like representation.

'`details`' Enable more detailed dumps (not honored by every dump option). Also include information from the optimization passes.

'`stats`' Enable dumping various statistics about the pass (not honored by every dump option).

'`blocks`' Enable showing basic block boundaries (disabled in raw dumps).

'`graph`' For each of the other indicated dump files (`-fdump-rtl-`*pass*), dump a representation of the control flow graph suitable for viewing with GraphViz to *file.passid.pass*`.dot`. Each function in the file is pretty-printed as a subgraph, so that GraphViz can render them all in a single plot.

RTL is always dumped in slim form.

'vops' Enable showing virtual operands for every statement.

'lineno' Enable showing line numbers for statements.

'uid' Enable showing the unique ID (DECL_UID) for each variable.

'verbose' Enable showing the tree dump for each statement.

'eh' Enable showing the EH region number holding each statement.

'scev' Enable showing scalar evolution analysis details.

'optimized'
Enable showing optimization information (only available in certain passes).

'missed' Enable showing missed optimization information (only available in certain passes).

'note' Enable other detailed optimization information (only available in certain passes).

'folding' Enable dumping information about match-and-simplify (match.pd) patterns, when they are applied.

'all' Turn on all options, except raw, slim, verbose and lineno.

'optall' Turn on all optimization options, i.e., optimized, missed, and note.

To determine what tree dumps are available or find the dump for a pass of interest follow the steps below.

1. Invoke GCC with -fdump-passes and in the stderr output look for a code that corresponds to the pass you are interested in. For example, the codes tree-evrp, tree-vrp1, and tree-vrp2 correspond to the three Value Range Propagation passes. The number at the end distinguishes distinct invocations of the same pass.
2. To enable the creation of the dump file, append the pass code to the -fdump- option prefix and invoke GCC with it. For example, to enable the dump from the Early Value Range Propagation pass, invoke GCC with the -fdump-tree-evrp option. Optionally, you may specify the name of the dump file. If you don't specify one, GCC creates as described below.
3. Find the pass dump in a file whose name is composed of three components separated by a period: the name of the source file GCC was invoked to compile, a numeric suffix indicating the pass number followed by the letter 't' for tree passes (and the letter 'r' for RTL passes), and finally the pass code. For example, the Early VRP pass dump might be in a file named myfile.c.038t.evrp in the current working directory. Note that the numeric codes are not stable and may change from one version of GCC to another.

`-fopt-info`
`-fopt-info-`*`options`*
`-fopt-info-`*`options`*`=`*`filename`*

Controls optimization dumps from various optimization passes. If the '`-`*`options`*' form is used, *options* is a list of '`-`' separated option keywords to select the dump details and optimizations.

The *options* can be divided into three groups:

1. options describing what kinds of messages should be emitted,
2. options describing the verbosity of the dump, and
3. options describing which optimizations should be included.

The options from each group can be freely mixed as they are non-overlapping. However, in case of any conflicts, the later options override the earlier options on the command line.

The following options control which kinds of messages should be emitted:

'`optimized`'
Print information when an optimization is successfully applied. It is up to a pass to decide which information is relevant. For example, the vectorizer passes print the source location of loops which are successfully vectorized.

'`missed`' Print information about missed optimizations. Individual passes control which information to include in the output.

'`note`' Print verbose information about optimizations, such as certain transformations, more detailed messages about decisions etc.

'`all`' Print detailed optimization information. This includes '`optimized`', '`missed`', and '`note`'.

The following option controls the dump verbosity:

'`internals`'
By default, only "high-level" messages are emitted. This option enables additional, more detailed, messages, which are likely to only be of interest to GCC developers.

One or more of the following option keywords can be used to describe a group of optimizations:

'`ipa`' Enable dumps from all interprocedural optimizations.

'`loop`' Enable dumps from all loop optimizations.

'`inline`' Enable dumps from all inlining optimizations.

'`omp`' Enable dumps from all OMP (Offloading and Multi Processing) optimizations.

'`vec`' Enable dumps from all vectorization optimizations.

'`optall`' Enable dumps from all optimizations. This is a superset of the optimization groups listed above.

If *options* is omitted, it defaults to '`optimized-optall`', which means to dump messages about successful optimizations from all the passes, omitting messages that are treated as "internals".

If the *filename* is provided, then the dumps from all the applicable optimizations are concatenated into the *filename*. Otherwise the dump is output onto `stderr`. Though multiple `-fopt-info` options are accepted, only one of them can include a *filename*. If other filenames are provided then all but the first such option are ignored.

Note that the output *filename* is overwritten in case of multiple translation units. If a combined output from multiple translation units is desired, `stderr` should be used instead.

In the following example, the optimization info is output to `stderr`:

```
gcc -O3 -fopt-info
```

This example:

```
gcc -O3 -fopt-info-missed=missed.all
```

outputs missed optimization report from all the passes into `missed.all`, and this one:

```
gcc -O2 -ftree-vectorize -fopt-info-vec-missed
```

prints information about missed optimization opportunities from vectorization passes on `stderr`. Note that `-fopt-info-vec-missed` is equivalent to `-fopt-info-missed-vec`. The order of the optimization group names and message types listed after `-fopt-info` does not matter.

As another example,

```
gcc -O3 -fopt-info-inline-optimized-missed=inline.txt
```

outputs information about missed optimizations as well as optimized locations from all the inlining passes into `inline.txt`.

Finally, consider:

```
gcc -fopt-info-vec-missed=vec.miss -fopt-info-loop-optimized=loop.opt
```

Here the two output filenames `vec.miss` and `loop.opt` are in conflict since only one output file is allowed. In this case, only the first option takes effect and the subsequent options are ignored. Thus only `vec.miss` is produced which contains dumps from the vectorizer about missed opportunities.

`-fsave-optimization-record`

Write a SRCFILE.opt-record.json.gz file detailing what optimizations were performed, for those optimizations that support `-fopt-info`.

This option is experimental and the format of the data within the compressed JSON file is subject to change.

It is roughly equivalent to a machine-readable version of `-fopt-info-all`, as a collection of messages with source file, line number and column number, with the following additional data for each message:

- the execution count of the code being optimized, along with metadata about whether this was from actual profile data, or just an estimate, allowing consumers to prioritize messages by code hotness,

- the function name of the code being optimized, where applicable,
- the "inlining chain" for the code being optimized, so that when a function is inlined into several different places (which might themselves be inlined), the reader can distinguish between the copies,
- objects identifying those parts of the message that refer to expressions, statements or symbol-table nodes, which of these categories they are, and, when available, their source code location,
- the GCC pass that emitted the message, and
- the location in GCC's own code from which the message was emitted

Additionally, some messages are logically nested within other messages, reflecting implementation details of the optimization passes.

`-fsched-verbose=`*`n`*

On targets that use instruction scheduling, this option controls the amount of debugging output the scheduler prints to the dump files.

For *n* greater than zero, `-fsched-verbose` outputs the same information as `-fdump-rtl-sched1` and `-fdump-rtl-sched2`. For *n* greater than one, it also output basic block probabilities, detailed ready list information and unit/insn info. For *n* greater than two, it includes RTL at abort point, control-flow and regions info. And for *n* over four, `-fsched-verbose` also includes dependence info.

`-fenable-`*`kind-pass`*
`-fdisable-`*`kind-pass=range-list`*

This is a set of options that are used to explicitly disable/enable optimization passes. These options are intended for use for debugging GCC. Compiler users should use regular options for enabling/disabling passes instead.

`-fdisable-ipa-`*`pass`*

Disable IPA pass *pass*. *pass* is the pass name. If the same pass is statically invoked in the compiler multiple times, the pass name should be appended with a sequential number starting from 1.

`-fdisable-rtl-`*`pass`*
`-fdisable-rtl-`*`pass=range-list`*

Disable RTL pass *pass*. *pass* is the pass name. If the same pass is statically invoked in the compiler multiple times, the pass name should be appended with a sequential number starting from 1. *range-list* is a comma-separated list of function ranges or assembler names. Each range is a number pair separated by a colon. The range is inclusive in both ends. If the range is trivial, the number pair can be simplified as a single number. If the function's call graph node's *uid* falls within one of the specified ranges, the *pass* is disabled for that function. The *uid* is shown in the function header of a dump file, and the pass names can be dumped by using option `-fdump-passes`.

`-fdisable-tree-`*pass*
`-fdisable-tree-`*pass*`=`*range-list*
: Disable tree pass *pass*. See `-fdisable-rtl` for the description of option arguments.

`-fenable-ipa-`*pass*
: Enable IPA pass *pass*. *pass* is the pass name. If the same pass is statically invoked in the compiler multiple times, the pass name should be appended with a sequential number starting from 1.

`-fenable-rtl-`*pass*
`-fenable-rtl-`*pass*`=`*range-list*
: Enable RTL pass *pass*. See `-fdisable-rtl` for option argument description and examples.

`-fenable-tree-`*pass*
`-fenable-tree-`*pass*`=`*range-list*
: Enable tree pass *pass*. See `-fdisable-rtl` for the description of option arguments.

Here are some examples showing uses of these options.

```
# disable ccp1 for all functions
   -fdisable-tree-ccp1
# disable complete unroll for function whose cgraph node uid is 1
   -fenable-tree-cunroll=1
# disable gcse2 for functions at the following ranges [1,1],
# [300,400], and [400,1000]
# disable gcse2 for functions foo and foo2
   -fdisable-rtl-gcse2=foo,foo2
# disable early inlining
   -fdisable-tree-einline
# disable ipa inlining
   -fdisable-ipa-inline
# enable tree full unroll
   -fenable-tree-unroll
```

`-fchecking`
`-fchecking=`*n*
: Enable internal consistency checking. The default depends on the compiler configuration. `-fchecking=2` enables further internal consistency checking that might affect code generation.

`-frandom-seed=`*string*
: This option provides a seed that GCC uses in place of random numbers in generating certain symbol names that have to be different in every compiled file. It is also used to place unique stamps in coverage data files and the object files that produce them. You can use the `-frandom-seed` option to produce reproducibly identical object files.

The *string* can either be a number (decimal, octal or hex) or an arbitrary string (in which case it's converted to a number by computing CRC32).

The *string* should be different for every file you compile.

`-save-temps`
`--save-temps`

Store the usual "temporary" intermediate files permanently; name them as auxiliary output files, as specified described under `-dumpbase` and `-dumpdir`.

When used in combination with the `-x` command-line option, `-save-temps` is sensible enough to avoid overwriting an input source file with the same extension as an intermediate file. The corresponding intermediate file may be obtained by renaming the source file before using `-save-temps`.

`-save-temps=cwd`

Equivalent to `-save-temps -dumpdir ./`.

`-save-temps=obj`

Equivalent to `-save-temps -dumpdir outdir/`, where `outdir/` is the directory of the output file specified after the `-o` option, including any directory separators. If the `-o` option is not used, the `-save-temps=obj` switch behaves like `-save-temps=cwd`.

`-time`[=*file*]

Report the CPU time taken by each subprocess in the compilation sequence. For C source files, this is the compiler proper and assembler (plus the linker if linking is done).

Without the specification of an output file, the output looks like this:

```
# cc1 0.12 0.01
# as 0.00 0.01
```

The first number on each line is the "user time", that is time spent executing the program itself. The second number is "system time", time spent executing operating system routines on behalf of the program. Both numbers are in seconds.

With the specification of an output file, the output is appended to the named file, and it looks like this:

```
0.12 0.01 cc1 options
0.00 0.01 as options
```

The "user time" and the "system time" are moved before the program name, and the options passed to the program are displayed, so that one can later tell what file was being compiled, and with which options.

`-fdump-final-insns`[=*file*]

Dump the final internal representation (RTL) to *file*. If the optional argument is omitted (or if *file* is `.`), the name of the dump file is determined by appending `.gkd` to the dump base name, see `-dumpbase`.

`-fcompare-debug`[=*opts*]

If no error occurs during compilation, run the compiler a second time, adding *opts* and `-fcompare-debug-second` to the arguments passed to the second compilation. Dump the final internal representation in both compilations, and print an error if they differ.

If the equal sign is omitted, the default `-gtoggle` is used.

The environment variable `GCC_COMPARE_DEBUG`, if defined, non-empty and nonzero, implicitly enables `-fcompare-debug`. If `GCC_COMPARE_DEBUG` is defined to a string starting with a dash, then it is used for *opts*, otherwise the default `-gtoggle` is used.

`-fcompare-debug=`, with the equal sign but without *opts*, is equivalent to `-fno-compare-debug`, which disables the dumping of the final representation and the second compilation, preventing even `GCC_COMPARE_DEBUG` from taking effect.

To verify full coverage during `-fcompare-debug` testing, set `GCC_COMPARE_DEBUG` to say `-fcompare-debug-not-overridden`, which GCC rejects as an invalid option in any actual compilation (rather than preprocessing, assembly or linking). To get just a warning, setting `GCC_COMPARE_DEBUG` to '`-w%n-fcompare-debug not overridden`' will do.

`-fcompare-debug-second`
: This option is implicitly passed to the compiler for the second compilation requested by `-fcompare-debug`, along with options to silence warnings, and omitting other options that would cause the compiler to produce output to files or to standard output as a side effect. Dump files and preserved temporary files are renamed so as to contain the `.gk` additional extension during the second compilation, to avoid overwriting those generated by the first.

When this option is passed to the compiler driver, it causes the *first* compilation to be skipped, which makes it useful for little other than debugging the compiler proper.

`-gtoggle`
: Turn off generation of debug info, if leaving out this option generates it, or turn it on at level 2 otherwise. The position of this argument in the command line does not matter; it takes effect after all other options are processed, and it does so only once, no matter how many times it is given. This is mainly intended to be used with `-fcompare-debug`.

`-fvar-tracking-assignments-toggle`
: Toggle `-fvar-tracking-assignments`, in the same way that `-gtoggle` toggles `-g`.

`-Q`
: When used on the command line prior to `--help=`, `-Q` acts as a modifier to the help output. See Section 3.2 [Overall Options], page 34, for details about `--help=`.

Otherwise, this option makes the compiler print out each function name as it is compiled, and print some statistics about each pass when it finishes.

`-ftime-report`
: Makes the compiler print some statistics to stderr about the time consumed by each pass when it finishes.

If SARIF output of diagnostics was requested via `-fdiagnostics-format=sarif-file` or `-fdiagnostics-format=sarif-stderr` then the `-ftime-report` information is instead emitted in JSON form as part of SARIF output. The precise format of this JSON data is subject to change, and the values may not exactly match those emitted to stderr due to being written out at a slightly different place within the compiler.

`-ftime-report-details`
Record the time consumed by infrastructure parts separately for each pass.

`-fira-verbose=n`
Control the verbosity of the dump file for the integrated register allocator. The default value is 5. If the value *n* is greater or equal to 10, the dump output is sent to stderr using the same format as *n* minus 10.

`-flto-report`
Prints a report with internal details on the workings of the link-time optimizer. The contents of this report vary from version to version. It is meant to be useful to GCC developers when processing object files in LTO mode (via `-flto`).

Disabled by default.

`-flto-report-wpa`
Like `-flto-report`, but only print for the WPA phase of link-time optimization.

`-fmem-report`
Makes the compiler print some statistics about permanent memory allocation when it finishes.

`-fmem-report-wpa`
Makes the compiler print some statistics about permanent memory allocation for the WPA phase only.

`-fpre-ipa-mem-report`
`-fpost-ipa-mem-report`
Makes the compiler print some statistics about permanent memory allocation before or after interprocedural optimization.

`-fmultiflags`
This option enables multilib-aware `TFLAGS` to be used to build target libraries with options different from those the compiler is configured to use by default, through the use of specs (see Section 3.21 [Spec Files], page 570) set up by compiler internals, by the target, or by builders at configure time.

Like `TFLAGS`, this allows the target libraries to be built for portable baseline environments, while the compiler defaults to more demanding ones. That's useful because users can easily override the defaults the compiler is configured to use to build their own programs, if the defaults are not ideal for their target environment, whereas rebuilding the runtime libraries is usually not as easy or desirable.

Unlike `TFLAGS`, the use of specs enables different flags to be selected for different multilibs. The way to accomplish that is to build with '`make TFLAGS=-fmultiflags`', after configuring '`--with-specs=%{fmultiflags:...}`'.

This option is discarded by the driver once it's done processing driver self spec.

It is also useful to check that `TFLAGS` are being used to build all target libraries, by configuring a non-bootstrap compiler '`--with-specs='%{!fmultiflags:%emissing TFLAGS}'`' and building the compiler and target libraries.

`-fprofile-report`
: Makes the compiler print some statistics about consistency of the (estimated) profile and effect of individual passes.

`-fstack-usage`
: Makes the compiler output stack usage information for the program, on a per-function basis. The filename for the dump is made by appending `.su` to the *auxname*. *auxname* is generated from the name of the output file, if explicitly specified and it is not an executable, otherwise it is the basename of the source file. An entry is made up of three fields:

- The name of the function.
- A number of bytes.
- One or more qualifiers: `static`, `dynamic`, `bounded`.

The qualifier `static` means that the function manipulates the stack statically: a fixed number of bytes are allocated for the frame on function entry and released on function exit; no stack adjustments are otherwise made in the function. The second field is this fixed number of bytes.

The qualifier `dynamic` means that the function manipulates the stack dynamically: in addition to the static allocation described above, stack adjustments are made in the body of the function, for example to push/pop arguments around function calls. If the qualifier `bounded` is also present, the amount of these adjustments is bounded at compile time and the second field is an upper bound of the total amount of stack used by the function. If it is not present, the amount of these adjustments is not bounded at compile time and the second field only represents the bounded part.

`-fstats`
: Emit statistics about front-end processing at the end of the compilation. This option is supported only by the C++ front end, and the information is generally only useful to the G++ development team.

`-fdbg-cnt-list`
: Print the name and the counter upper bound for all debug counters.

`-fdbg-cnt=counter-value-list`
: Set the internal debug counter lower and upper bound. *counter-value-list* is a comma-separated list of *name*:*lower_bound1*-*upper_bound1* [:*lower_bound2*-*upper_bound2*...] tuples which sets the name of the counter and list of closed intervals. The *lower_bound* is optional and is zero initialized if not set. For example, with `-fdbg-cnt=dce:2-4:10-11,tail_call:10`, `dbg_cnt(dce)` returns true only for second, third, fourth, tenth and eleventh invocation. For `dbg_cnt(tail_call)` true is returned for first 10 invocations.

`-print-file-name=library`
`--print-file-name=library`
`--print-file-name library`
: Print the full absolute name of the library file *library* that would be used when linking—and don't do anything else. With this option, GCC does not compile or link anything; it just prints the file name.

`-print-multi-directory`
`--print-multi-directory`

Print the directory name corresponding to the multilib selected by any other switches present in the command line. This directory is supposed to exist in `GCC_EXEC_PREFIX`.

`-print-multi-lib`
`--print-multi-lib`

Print the mapping from multilib directory names to compiler switches that enable them. The directory name is separated from the switches by '`;`', and each switch starts with an '`@`' instead of the '`-`', without spaces between multiple switches. This is supposed to ease shell processing.

`-print-multi-os-directory`
`--print-multi-os-directory`

Print the path to OS libraries for the selected multilib, relative to some `lib` subdirectory. If OS libraries are present in the `lib` subdirectory and no multilibs are used, this is usually just `.`, if OS libraries are present in `lib`*suffix* sibling directories this prints e.g. `../lib64`, `../lib` or `../lib32`, or if OS libraries are present in `lib/`*subdir* subdirectories it prints e.g. `amd64`, `sparcv9` or `ev6`.

`-print-multiarch`
`--print-multiarch`

Print the path to OS libraries for the selected multiarch, relative to some `lib` subdirectory.

`-print-prog-name=`*program*
`--print-prog-name=`*program*
`--print-prog-name` *program*

Like `-print-file-name`, but searches for a program such as `cpp`.

`-print-libgcc-file-name`
`--print-libgcc-file-name`

Same as `-print-file-name=libgcc.a`.

This is useful when you use `-nostdlib` or `-nodefaultlibs` but you do want to link with `libgcc.a`. You can do:

```
gcc -nostdlib files... `gcc -print-libgcc-file-name`
```

`-print-search-dirs`
`--print-search-dirs`

Print the name of the configured installation directory and a list of program and library directories `gcc` searches—and don't do anything else.

This is useful when `gcc` prints the error message '`installation problem, cannot exec cpp0: No such file or directory`'. To resolve this you either need to put `cpp0` and the other compiler components where `gcc` expects to find them, or you can set the environment variable `GCC_EXEC_PREFIX` to the directory where you installed them. Don't forget the trailing '`/`'. See Section 3.22 [Environment Variables], page 579.

`-print-sysroot`
`--print-sysroot`

Print the target sysroot directory that is used during compilation. This is the target sysroot specified either at configure time or using the `--sysroot` option, possibly with an extra suffix that depends on compilation options. If no target sysroot is specified, the option prints nothing.

`-print-sysroot-headers-suffix`
`--print-sysroot-headers-suffix`

Print the suffix added to the target sysroot when searching for headers, or give an error if the compiler is not configured with such a suffix—and don't do anything else.

`-dumpmachine`

Print the compiler's target machine (for example, '`i686-pc-linux-gnu`')—and don't do anything else.

`-dumpversion`

Print the compiler version (for example, `3.0`, `6.3.0` or `7`)—and don't do anything else. This is the compiler version used in filesystem paths and specs. Depending on how the compiler has been configured it can be just a single number (major version), two numbers separated by a dot (major and minor version) or three numbers separated by dots (major, minor and patchlevel version).

`-dumpfullversion`

Print the full compiler version—and don't do anything else. The output is always three numbers separated by dots, major, minor and patchlevel version.

`-dumpspecs`

Print the compiler's built-in specs—and don't do anything else. (This is used when GCC itself is being built.) See Section 3.21 [Spec Files], page 570.

3.20 Machine-Dependent Options

Each target machine supported by GCC can have its own options—for example, to allow you to compile for a particular processor variant or ABI, or to control optimizations specific to that machine. By convention, the names of machine-specific options start with '`-m`'.

Some configurations of the compiler also support additional target-specific options, usually for compatibility with other compilers on the same platform.

3.20.1 AArch64 Options

These options are defined for AArch64 implementations:

`-mabi=`*name*

Generate code for the specified data model. Permissible values are '`ilp32`' for SysV-like data model where int, long int and pointers are 32 bits, and '`lp64`' for SysV-like data model where int is 32 bits, but long int and pointers are 64 bits.

The default depends on the specific target configuration. Note that the LP64 and ILP32 ABIs are not link-compatible; you must compile your entire program with the same ABI, and link with a compatible set of libraries.

The 'ilp32' model is deprecated.

-mbig-endian
: Generate big-endian code. This is the default when GCC is configured for an 'aarch64_be-*-*' target.

-mlittle-endian
: Generate little-endian code. This is the default when GCC is configured for an 'aarch64-*-*' but not an 'aarch64_be-*-*' target.

-menable-sysreg-checking
: Generates an error message if an attempt is made to access a system register which is not available on the target architecture.

-mgeneral-regs-only
: Generate code that uses only the general-purpose registers. This prevents the compiler from using floating-point and Advanced SIMD registers but does not impose any restrictions on the assembler.

-mcmodel=tiny
: Generate code for the tiny code model. The program and its statically defined symbols must be within 1MB of each other. Programs can be statically or dynamically linked.

-mcmodel=small
: Generate code for the small code model. The program and its statically defined symbols must be within 4GB of each other. Programs can be statically or dynamically linked. This is the default code model.

-mcmodel=large
: Generate code for the large code model. This makes no assumptions about addresses and sizes of sections. Programs can be statically linked only. The -mcmodel=large option is incompatible with -mabi=ilp32, -fpic and -fPIC.

-mtp=*name*
: Specify the system register to use as a thread pointer. The valid values are 'tpidr_el0', 'tpidrro_el0', 'tpidr_el1', 'tpidr_el2', 'tpidr_el3'. For backwards compatibility the aliases 'el0', 'el1', 'el2', 'el3' are also accepted. The default setting is 'tpidr_el0'. It is recommended to compile all code intended to interoperate with the same value of this option to avoid accessing a different thread pointer from the wrong exception level.

-mstrict-align
-mno-strict-align
: Avoid or allow generating memory accesses that may not be aligned on a natural object boundary as described in the architecture specification.

`-momit-leaf-frame-pointer`
`-mno-omit-leaf-frame-pointer`
: Omit or keep the frame pointer in leaf functions. The former behavior is the default.

`-mstack-protector-guard=`*`guard`*
`-mstack-protector-guard-reg=`*`reg`*
`-mstack-protector-guard-offset=`*`offset`*
: Generate stack protection code using canary at *guard*. Supported locations are '`global`' for a global canary or '`sysreg`' for a canary in an appropriate system register.

  With the latter choice the options `-mstack-protector-guard-reg=`*`reg`* and `-mstack-protector-guard-offset=`*`offset`* furthermore specify which system register to use as base register for reading the canary, and from what offset from that base register. There is no default register or offset as this is entirely for use within the Linux kernel.

`-mtls-dialect=desc`
: Use TLS descriptors as the thread-local storage mechanism for dynamic accesses of TLS variables. This is the default.

`-mtls-dialect=traditional`
: Use traditional TLS as the thread-local storage mechanism for dynamic accesses of TLS variables.

`-mtls-size=`*`size`*
: Specify bit size of immediate TLS offsets. Valid values are 12, 24, 32, 48. This option requires binutils 2.26 or newer.

`-mfix-cortex-a53-835769`
`-mno-fix-cortex-a53-835769`
: Enable or disable the workaround for the ARM Cortex-A53 erratum number 835769. This involves inserting a NOP instruction between memory instructions and 64-bit integer multiply-accumulate instructions. This flag will be ignored if an architecture or cpu is specified on the command line which does not need the workaround.

`-mfix-cortex-a53-843419`
`-mno-fix-cortex-a53-843419`
: Enable or disable the workaround for the ARM Cortex-A53 erratum number 843419. This erratum workaround is made at link time and this will only pass the corresponding flag to the linker. This flag will be ignored if an architecture or cpu is specified on the command line which does not need the workaround.

`-mlow-precision-recip-sqrt`
`-mno-low-precision-recip-sqrt`
: Enable or disable the reciprocal square root approximation. This option only has an effect if `-ffast-math` or `-funsafe-math-optimizations` is used as well. Enabling this reduces precision of reciprocal square root results to about 16 bits for single precision and to 32 bits for double precision.

`-mlow-precision-sqrt`
`-mno-low-precision-sqrt`
: Enable or disable the square root approximation. This option only has an effect if `-ffast-math` or `-funsafe-math-optimizations` is used as well. Enabling this reduces precision of square root results to about 16 bits for single precision and to 32 bits for double precision. If enabled, it implies `-mlow-precision-recip-sqrt`.

`-mlow-precision-div`
`-mno-low-precision-div`
: Enable or disable the division approximation. This option only has an effect if `-ffast-math` or `-funsafe-math-optimizations` is used as well. Enabling this reduces precision of division results to about 16 bits for single precision and to 32 bits for double precision.

`-mtrack-speculation`
`-mno-track-speculation`
: Enable or disable generation of additional code to track speculative execution through conditional branches. The tracking state can then be used by the compiler when expanding calls to `__builtin_speculation_safe_copy` to permit a more efficient code sequence to be generated.

`-moutline-atomics`
`-mno-outline-atomics`
: Enable or disable calls to out-of-line helpers to implement atomic operations. These helpers will, at runtime, determine if the LSE instructions from ARMv8.1-A can be used; if not, they will use the load/store-exclusive instructions that are present in the base ARMv8.0 ISA.

  This option is only applicable when compiling for the base ARMv8.0 instruction set. If using a later revision, e.g. `-march=armv8.1-a` or `-march=armv8-a+lse`, the ARMv8.1-Atomics instructions will be used directly. The same applies when using `-mcpu=` when the selected cpu supports the '`lse`' feature. This option is on by default.

`-mmax-vectorization`
`-mno-max-vectorization`
: Enable or disable an override to vectorizer cost model making vectorization always appear profitable. This option can be combined with `-mautovec-preference` allowing precise control over which ISA will be used for auto-vectorization. Unlike `-fno-vect-cost-model` or `-fvect-cost-model=unlimited` this option does not turn off cost comparison between different vector modes.

`-mautovec-preference=`*`name`*
: Force an ISA selection strategy for auto-vectorization. The possible values of *name* are:

  '`default`' Use the default heuristics.

  '`asimd-only`'
  : Use only Advanced SIMD for auto-vectorization.

'sve-only'
: Use only SVE for auto-vectorization.

'prefer-asimd'
: Use both Advanced SIMD and SVE. Prefer Advanced SIMD when the costs are deemed equal.

'prefer-sve'
: Use both Advanced SIMD and SVE. Prefer SVE when the costs are deemed equal.

For best performance it is highly recommended to use `-mcpu` or `-mtune` instead. This parameter should only be used for code exploration.

`-march=`*name*

Specify the name of the target architecture and, optionally, one or more feature modifiers. This option has the form `-march=`*arch*{`+`[`no`]*feature*}*.

The table below summarizes the permissible values for *arch* and the features that they enable by default:

arch **value**	**Architecture**	**Includes by default**
'armv8-a'	Armv8-A	'+fp', '+simd'
'armv8.1-a'	Armv8.1-A	'armv8-a', '+crc', '+lse', '+rdma'
'armv8.2-a'	Armv8.2-A	'armv8.1-a'
'armv8.3-a'	Armv8.3-A	'armv8.2-a', '+pauth', '+fcma', '+jscvt'
'armv8.4-a'	Armv8.4-A	'armv8.3-a', '+flagm', '+fp16fml', '+dotprod', '+rcpc2'
'armv8.5-a'	Armv8.5-A	'armv8.4-a', '+sb', '+ssbs', '+predres', '+frintts', '+flagm2'
'armv8.6-a'	Armv8.6-A	'armv8.5-a', '+bf16', '+i8mm'
'armv8.7-a'	Armv8.7-A	'armv8.6-a', '+wfxt', '+xs'
'armv8.8-a'	Armv8.8-a	'armv8.7-a', '+mops'
'armv8.9-a'	Armv8.9-a	'armv8.8-a'
'armv9-a'	Armv9-A	'armv8.5-a', '+sve', '+sve2'
'armv9.1-a'	Armv9.1-A	'armv9-a', '+bf16', '+i8mm'
'armv9.2-a'	Armv9.2-A	'armv9.1-a', '+wfxt', '+xs'
'armv9.3-a'	Armv9.3-A	'armv9.2-a', '+mops'
'armv9.4-a'	Armv9.4-A	'armv9.3-a', '+sve2p1'
'armv9.5-a'	Armv9.5-A	'armv9.4-a', 'cpa', '+faminmax', '+lut'
'armv8-r'	Armv8-R	'armv8-r'

The value 'native' is available on native AArch64 GNU/Linux and causes the compiler to pick the architecture of the host system. This option has no effect if the compiler is unable to recognize the architecture of the host system. When `-march=native` is given and no other `-mcpu` or `-mtune` is given then GCC will pick the host CPU as the CPU to tune for as well as select the architecture features from. That is, `-march=native` is treated as `-mcpu=native`.

The permissible values for *feature* are listed in the sub-section on [`-march` and `-mcpu` Feature Modifiers], page 353. Where conflicting feature modifiers are specified, the right-most feature is used.

GCC uses *name* to determine what kind of instructions it can emit when generating assembly code. If `-march` is specified without either of `-mtune` or `-mcpu` also being specified, the code is tuned to perform well across a range of target processors implementing the target architecture.

`-mtune=`*name*

Specify the name of the target processor for which GCC should tune the performance of the code. Permissible values for this option are: '`generic`', '`cortex-a35`', '`cortex-a53`', '`cortex-a55`', '`cortex-a57`', '`cortex-a72`', '`cortex-a73`', '`cortex-a75`', '`cortex-a76`', '`cortex-a76ae`', '`cortex-a77`', '`cortex-a65`', '`cortex-a65ae`', '`cortex-a34`', '`cortex-a78`', '`cortex-a78ae`', '`cortex-a78c`', '`ares`', '`exynos-m1`', '`emag`', '`falkor`', '`oryon-1`', '`neoverse-512tvb`', '`neoverse-e1`', '`neoverse-n1`', '`neoverse-n2`', '`neoverse-v1`', '`neoverse-v2`', '`grace`', '`neoverse-v3`', '`neoverse-v3ae`', '`neoverse-n3`', '`olympus`', '`cortex-a725`', '`cortex-x925`', '`qdf24xx`', '`saphira`', '`phecda`', '`xgene1`', '`vulcan`', '`octeontx`', '`octeontx81`', '`octeontx83`', '`octeontx2`', '`octeontx2t98`', '`octeontx2t96`' '`octeontx2t93`', '`octeontx2f95`', '`octeontx2f95n`', '`octeontx2f95mm`', '`a64fx`', '`fujitsu-monaka`', '`thunderx`', '`thunderxt88`', '`thunderxt88p1`', '`thunderxt81`', '`tsv110`', '`thunderxt83`', '`thunderx2t99`', '`thunderx3t110`', '`zeus`', '`cortex-a57.cortex-a53`', '`cortex-a72.cortex-a53`', '`cortex-a73.cortex-a35`', '`cortex-a73.cortex-a53`', '`cortex-a75.cortex-a55`', '`cortex-a76.cortex-a55`', '`cortex-r82`', '`cortex-r82ae`', '`cortex-x1`', '`cortex-x1c`', '`cortex-x2`', '`cortex-x3`', '`cortex-x4`', '`cortex-a510`', '`cortex-a520`', '`cortex-a520ae`', '`cortex-a710`', '`cortex-a715`', '`cortex-a720`', '`cortex-a720ae`', '`ampere1`', '`ampere1a`', '`ampere1b`', '`ampere1c`', '`cobalt-100`', '`apple-m1`', '`apple-m2`', '`apple-m3`', '`apple-m4`' and '`native`'.

The values '`cortex-a57.cortex-a53`', '`cortex-a72.cortex-a53`', '`cortex-a73.cortex-a35`', '`cortex-a73.cortex-a53`', '`cortex-a75.cortex-a55`', '`cortex-a76.cortex-a55`', '`apple-m1`', '`apple-m2`', '`apple-m3`', '`gb10`' specify that GCC should tune for a big.LITTLE system.

The value '`neoverse-512tvb`' specifies that GCC should tune for Neoverse cores that (a) implement SVE and (b) have a total vector bandwidth of 512 bits per cycle. In other words, the option tells GCC to tune for Neoverse cores that can execute 4 128-bit Advanced SIMD arithmetic instructions a cycle and that can execute an equivalent number of SVE arithmetic instructions per cycle (2 for 256-bit SVE, 4 for 128-bit SVE). This is more general than tuning for a specific core like Neoverse V1 but is more specific than the default tuning described below.

Additionally on native AArch64 GNU/Linux systems the value '`native`' tunes performance to the host system. This option has no effect if the compiler is unable to recognize the processor of the host system.

Where none of `-mtune=`, `-mcpu=` or `-march=` are specified, the code is tuned to perform well across a range of target processors.

This option cannot be suffixed by feature modifiers.

`-mcpu=name`

Specify the name of the target processor, optionally suffixed by one or more feature modifiers. This option has the form `-mcpu=cpu{+[no]feature}*`, where the permissible values for *cpu* are the same as those available for `-mtune`. The permissible values for *feature* are documented in the sub-section on [-march and -mcpu Feature Modifiers], page 353. Where conflicting feature modifiers are specified, the right-most feature is used.

GCC uses *name* to determine what kind of instructions it can emit when generating assembly code (as if by `-march`) and to determine the target processor for which to tune for performance (as if by `-mtune`). Where this option is used in conjunction with `-march` or `-mtune`, those options take precedence over the appropriate part of this option.

`-mcpu=neoverse-512tvb` is special in that it does not refer to a specific core, but instead refers to all Neoverse cores that (a) implement SVE and (b) have a total vector bandwidth of 512 bits a cycle. Unless overridden by `-march`, `-mcpu=neoverse-512tvb` generates code that can run on a Neoverse V1 core, since Neoverse V1 is the first Neoverse core with these properties. Unless overridden by `-mtune`, `-mcpu=neoverse-512tvb` tunes code in the same way as for `-mtune=neoverse-512tvb`.

`-moverride=string`

Override tuning decisions made by the back-end in response to a `-mtune=` switch. The syntax, semantics, and accepted values for *string* in this option are not guaranteed to be consistent across releases.

This option is only intended to be useful when developing GCC.

`-mpc-relative-literal-loads`
`-mno-pc-relative-literal-loads`

Enable or disable PC-relative literal loads. With this option literal pools are accessed using a single instruction and emitted after each function. This limits the maximum size of functions to 1MB. This is enabled by default for `-mcmodel=tiny`.

`-msign-return-address=scope`

Select the function scope on which return address signing will be applied. Permissible values are '`none`', which disables return address signing, '`non-leaf`', which enables pointer signing for functions which are not leaf functions, and '`all`', which enables pointer signing for all functions. The default value is '`none`'. This option has been deprecated by `-mbranch-protection`.

`-mbranch-protection=features`

Select the branch protection features to use. *features* can have one of the following forms:

'`none`' is the default and turns off all types of branch protection.

'`standard`' turns on all types of branch protection features. If a feature has additional tuning options, then '`standard`' sets it to its standard level.

'pac-ret' turns on return address signing to its standard level: signing functions that save the return address to memory (non-leaf functions practically always do this) using the A-key.

'pac-ret+leaf' extends the 'pac-ret' signing to include leaf functions.

'pac-ret+b-key' or 'pac-ret+leaf+b-key' can be used to sign the functions with the B-key instead of the A-key.

'bti' turns on branch target identification mechanism.

'gcs' turns on guarded control stack compatible code generation.

`-mharden-sls=`*opts*
: Enable compiler hardening against straight line speculation (SLS). *opts* is a comma-separated list of the following options:

'retbr'

'blr'

In addition, '-mharden-sls=all' enables all SLS hardening while '-mharden-sls=none' disables all SLS hardening.

`-mearly-ra=`*scope*
: Determine when to enable an early register allocation pass. This pass runs before instruction scheduling and tries to find a spill-free allocation of floating-point and vector code. It also tries to make use of strided multi-register instructions, such as SME2's strided LD1 and ST1.

The possible values of *scope* are: *all*, which runs the pass on all functions; *strided*, which runs the pass on functions that have access to strided multi-register instructions; and *none*, which disables the pass.

`-mearly-ra=all` is the default for `-O2` and above, and for `-Os`. `-mearly-ra=none` is the default otherwise.

`-mearly-ldp-fusion`
`-mno-early-ldp-fusion`
: Enable the copy of the AArch64 load/store pair fusion pass that runs before register allocation. Enabled by default at '-O' and above.

`-mlate-ldp-fusion`
`-mno-late-ldp-fusion`
: Enable the copy of the AArch64 load/store pair fusion pass that runs after register allocation. Enabled by default at '-O' and above.

`-msve-vector-bits=`*bits*
: Specify the number of bits in an SVE vector register. This option only has an effect when SVE is enabled.

GCC supports two forms of SVE code generation: "vector-length agnostic" output that works with any size of vector register and "vector-length specific" output that allows GCC to make assumptions about the vector length when it is useful for optimization reasons. The possible values of 'bits' are: 'scalable', '128', '256', '512', '1024' and '2048'. Specifying 'scalable' selects vector-length agnostic output. At present '-msve-vector-bits=128' also generates vector-length agnostic output for big-endian targets. All other values generate vector-length specific code. The behavior of these values may change in future releases and no value except '`scalable`' should be relied on for producing code that is portable across different hardware SVE vector lengths.

The default is '`-msve-vector-bits=scalable`', which produces vector-length agnostic code.

3.20.1.1 `-march` and `-mcpu` Feature Modifiers

Feature modifiers used with `-march` and `-mcpu` can be any of the following and their inverses `no`*`feature`*:

'`crc`' Enable CRC extension. This is on by default for `-march=armv8.1-a`.

'`crypto`' Enable Crypto extension. This also enables Advanced SIMD and floating-point instructions.

'`fp`' Enable floating-point instructions. This is on by default for all possible values for options `-march` and `-mcpu`.

'`simd`' Enable Advanced SIMD instructions. This also enables floating-point instructions. This is on by default for all possible values for options `-march` and `-mcpu`.

'`sve`' Enable Scalable Vector Extension instructions. This also enables Advanced SIMD and floating-point instructions.

'`lse`' Enable Large System Extension instructions. This is on by default for `-march=armv8.1-a`.

'`rdma`' Enable Round Double Multiply Accumulate instructions. This is on by default for `-march=armv8.1-a`.

'`fp16`' Enable FP16 extension. This also enables floating-point instructions.

'`fp16fml`' Enable FP16 fmla extension. This also enables FP16 extensions and floating-point instructions. This option is enabled by default for `-march=armv8.4-a`. Use of this option with architectures prior to Armv8.2-A is not supported.

'`rcpc`' Enable the RCpc extension. This enables the use of the LDAPR instructions for load-acquire atomic semantics, and passes it on to the assembler, enabling inline asm statements to use instructions from the RCpc extension.

'`dotprod`' Enable the Dot Product extension. This also enables Advanced SIMD instructions.

'`aes`' Enable the Armv8-a aes and pmull crypto extension. This also enables Advanced SIMD instructions.

'`sha2`' Enable the Armv8-a sha2 crypto extension. This also enables Advanced SIMD instructions.

'`sha3`' Enable the sha512 and sha3 crypto extension. This also enables Advanced SIMD instructions. Use of this option with architectures prior to Armv8.2-A is not supported.

'sm4' Enable the sm3 and sm4 crypto extension. This also enables Advanced SIMD instructions. Use of this option with architectures prior to Armv8.2-A is not supported.

'profile' Enable the Statistical Profiling extension. This option is only to enable the extension at the assembler level and does not affect code generation.

'rng' Enable the Armv8.5-a Random Number instructions. This option is only to enable the extension at the assembler level and does not affect code generation.

'memtag' Enable the Armv8.5-a Memory Tagging Extensions. Use of this option with architectures prior to Armv8.5-A is not supported.

'sb' Enable the Armv8-a Speculation Barrier instruction. This option is only to enable the extension at the assembler level and does not affect code generation. This option is enabled by default for `-march=armv8.5-a`.

'ssbs' Enable the Armv8-a Speculative Store Bypass Safe instruction. This option is only to enable the extension at the assembler level and does not affect code generation. This option is enabled by default for `-march=armv8.5-a`.

'predres' Enable the Armv8-a Execution and Data Prediction Restriction instructions. This option is only to enable the extension at the assembler level and does not affect code generation. This option is enabled by default for `-march=armv8.5-a`.

'sve2' Enable the Armv8-a Scalable Vector Extension 2. This also enables SVE instructions.

'sve2-bitperm'
Enable SVE2 bitperm instructions. This also enables SVE2 instructions.

'sve2-sm4'
Enable SVE2 sm4 instructions. This also enables SVE2 instructions.

'sve2-aes'
Enable SVE2 aes instructions. This also enables SVE2 instructions.

'sve2-sha3'
Enable SVE2 sha3 instructions. This also enables SVE2 instructions.

'sve2p1' Enable SVE2.1 instructions. This also enables SVE2 instructions.

'tme' Enable the Transactional Memory Extension.

'i8mm' Enable 8-bit Integer Matrix Multiply instructions. This also enables Advanced SIMD and floating-point instructions. This option is enabled by default for `-march=armv8.6-a`. Use of this option with architectures prior to Armv8.2-A is not supported.

'f32mm' Enable 32-bit Floating point Matrix Multiply instructions. This also enables SVE instructions. Use of this option with architectures prior to Armv8.2-A is not supported.

'f64mm' Enable 64-bit Floating point Matrix Multiply instructions. This also enables SVE instructions. Use of this option with architectures prior to Armv8.2-A is not supported.

'bf16' Enable brain half-precision floating-point instructions. This also enables Advanced SIMD and floating-point instructions. This option is enabled by default for `-march=armv8.6-a`. Use of this option with architectures prior to Armv8.2-A is not supported.

'ls64' Enable the 64-byte atomic load and store instructions for accelerators.

'mops' Enable the instructions to accelerate memory operations like `memcpy`, `memmove`, `memset`. This option is enabled by default for `-march=armv8.8-a`

'flagm' Enable the Flag Manipulation instructions Extension.

'flagm2' Enable the FlagM2 flag conversion instructions.

'pauth' Enable the Pointer Authentication Extension.

'cssc' Enable the Common Short Sequence Compression instructions.

'cmpbr' Enable the shorter compare and branch instructions, `cbb`, `cbh` and `cb`.

'sme' Enable the Scalable Matrix Extension. This is only supported when SVE2 is also enabled.

'sme-i16i64'
Enable the FEAT_SME_I16I64 extension to SME. This also enables SME instructions.

'sme-f64f64'
Enable the FEAT_SME_F64F64 extension to SME. This also enables SME instructions.

'sme2' Enable the Scalable Matrix Extension 2. This also enables SME instructions.

'sme-b16b16'
Enable the FEAT_SME_B16B16 extension to SME. This also enables SME2 and SVE_B16B16 instructions.

'sme-f16f16'
Enable the FEAT_SME_F16F16 extension to SME. This also enables SME2 instructions.

'sme2p1' Enable the Scalable Matrix Extension version 2.1. This also enables SME2 instructions.

'fcma' Enable the complex number SIMD extensions.

'jscvt' Enable the `fjcvtzs` JavaScript conversion instruction.

'frintts' Enable floating-point round to integral value instructions.

'wfxt' Enable `wfet` and `wfit` instructions.

'xs' Enable the XS memory attribute extension.

'lse128' Enable the LSE128 128-bit atomic instructions extension. This also enables LSE instructions.

'd128' Enable support for 128-bit system register read/write instructions. This also enables the LSE128 extension.

'gcs' Enable support for Armv9.4-a Guarded Control Stack extension.

'the' Enable support for Armv8.9-a/9.4-a translation hardening extension.

'rcpc2' Enable the RCpc2 extension.

'rcpc3' Enable the RCpc3 (Release Consistency) extension.

'fp8' Enable the fp8 (8-bit floating point) extension.

'fp8fma' Enable the fp8 (8-bit floating point) multiply accumulate extension.

'ssve-fp8fma'
Enable the fp8 (8-bit floating point) multiply accumulate extension in streaming mode.

'fp8dot4' Enable the fp8 (8-bit floating point) to single-precision 4-way dot product extension.

'ssve-fp8dot4'
Enable the fp8 (8-bit floating point) to single-precision 4-way dot product extension in streaming mode.

'fp8dot2' Enable the fp8 (8-bit floating point) to half-precision 2-way dot product extension.

'ssve-fp8dot2'
Enable the fp8 (8-bit floating point) to half-precision 2-way dot product extension in streaming mode.

'faminmax'
Enable the Floating Point Absolute Maximum/Minimum extension.

'lut' Enable the Lookup Table extension.

'sme-lutv2'
Enable the SME Lookup Table v2 (LUTv2) extension.

'cpa' Enable the Checked Pointer Arithmetic instructions.

'sve-b16b16'
Enable the SVE non-widening brain floating-point (`bf16`) extension. This only has an effect when `sve2` or `sme2` are also enabled.

Feature `crypto` implies `aes`, `sha2`, and `simd`, which implies `fp`. Conversely, `nofp` implies `nosimd`, which implies `nocrypto`, `noaes` and `nosha2`.

3.20.2 Adapteva Epiphany Options

These '-m' options are defined for Adapteva Epiphany:

`-mhalf-reg-file`
`-mno-half-reg-file`
Don't allocate any register in the range `r32...r63`. That allows code to run on hardware variants that lack these registers.

`-mprefer-short-insn-regs`
`-mno-prefer-short-insn-regs`
Preferentially allocate registers that allow short instruction generation. This can result in increased instruction count, so this may either reduce or increase overall code size.

`-mbranch-cost=`*num*
Set the cost of branches to roughly *num* "simple" instructions. This cost is only a heuristic and is not guaranteed to produce consistent results across releases.

`-mcmove`
`-mno-cmove`
Enable the generation of conditional moves.

`-mnops=`*num*
Emit *num* NOPs before every other generated instruction.

`-mno-soft-cmpsf`
`-msoft-cmpsf`
For single-precision floating-point comparisons, emit an `fsub` instruction and test the flags. This is faster than a software comparison, but can get incorrect results in the presence of NaNs, or when two different small numbers are compared such that their difference is calculated as zero. The default is `-msoft-cmpsf`, which uses slower, but IEEE-compliant, software comparisons.

`-mstack-offset=`*num*
Set the offset between the top of the stack and the stack pointer. E.g., a value of 8 means that the eight bytes in the range `sp+0...sp+7` can be used by leaf functions without stack allocation. Values other than '8' or '16' are untested and unlikely to work. Note also that this option changes the ABI; compiling a program with a different stack offset than the libraries have been compiled with generally does not work. This option can be useful if you want to evaluate if a different stack offset would give you better code, but to actually use a different stack offset to build working programs, it is recommended to configure the toolchain with the appropriate `--with-stack-offset=`*num* option.

`-mno-round-nearest`
`-mround-nearest`
`-mno-round-nearest` makes the scheduler assume that the rounding mode has been set to truncating. The default is `-mround-nearest`.

`-mlong-calls`
If not otherwise specified by an attribute, assume all calls might be beyond the offset range of the `b` / `bl` instructions, and therefore load the function address into a register before performing a (otherwise direct) call. This is the default.

`-mshort-calls`
If not otherwise specified by an attribute, assume all direct calls are in the range of the `b` / `bl` instructions, so use these instructions for direct calls.

The default is `-mlong-calls`. Note that `-mlong-calls` is equivalent to `-mno-short-calls`, and similarly `-mno-long-calls` is equivalent to `-mshort-calls`.

`-msmall16`
`-mno-small16`
Assume addresses can be loaded as 16-bit unsigned values. This does not apply to function addresses for which `-mlong-calls` semantics are in effect.

`-mfp-mode=`*mode*
Set the prevailing mode of the floating-point unit. This determines the floating-point mode that is provided and expected at function call and return time. Making this mode match the mode you predominantly need at function start can make your programs smaller and faster by avoiding unnecessary mode switches.

mode can be set to one the following values:

'`caller`' Any mode at function entry is valid, and retained or restored when the function returns, and when it calls other functions. This mode is useful for compiling libraries or other compilation units you might want to incorporate into different programs with different prevailing FPU modes, and the convenience of being able to use a single object file outweighs the size and speed overhead for any extra mode switching that might be needed, compared with what would be needed with a more specific choice of prevailing FPU mode.

'`truncate`'
This is the mode used for floating-point calculations with truncating (i.e. round towards zero) rounding mode. That includes conversion from floating point to integer.

'`round-nearest`'
This is the mode used for floating-point calculations with round-to-nearest-or-even rounding mode.

'`int`' This is the mode used to perform integer calculations in the FPU, e.g. integer multiply, or integer multiply-and-accumulate.

The default is `-mfp-mode=caller`

`-mmay-round-for-trunc`
`-mno-may-round-for-trunc`
This option allows floating point to integer truncation to be replaced with rounding to save mode switching. It's disabled by default.

`-mfp-iarith`
`-mno-fp-iarith`
This option enables use of the floating-point unit for integer add and subtract. It's disabled by default.

`-msplit-lohi`
`-mno-split-lohi`
`-mpost-inc`
`-mno-post-inc`
`-mpost-modify`
`-mno-post-modify`

Code generation tweaks that control, respectively, splitting of 32-bit loads, generation of post-increment addresses, and generation of post-modify addresses. The defaults are `msplit-lohi`, `-mpost-inc`, and `-mpost-modify`.

`-mno-vect-double`

Change the preferred SIMD mode to SImode. The default is `-mvect-double`, which uses DImode as preferred SIMD mode.

`-max-vect-align=`*num*

The maximum alignment for SIMD vector mode types. *num* may be 4 or 8. The default is 8. Note that this is an ABI change, even though many library function interfaces are unaffected if they don't use SIMD vector modes in places that affect size and/or alignment of relevant types.

`-msplit-vecmove-early`
`-mno-split-vecmove-early`

Split vector moves into single word moves before reload. In theory this can give better register allocation, but so far the reverse seems to be generally the case.

`-m1reg-`*reg*

Specify a register to hold the constant −1, which makes loading small negative constants and certain bitmasks faster. Allowable values for *reg* are '`r43`' and '`r63`', which specify use of that register as a fixed register, and '`none`', which means that no register is used for this purpose. The default is `-m1reg-none`.

3.20.3 AMD GCN Options

These options are defined specifically for the AMD GCN port.

`-march=`*gpu*
`-mtune=`*gpu*

Set architecture type or tuning for *gpu*. Supported values for *gpu* are

'`gfx900`' Compile for GCN5 Vega 10 devices (gfx900).

'`gfx902`' Compile for GCN5 Vega gfx902 devices. (Experimental)

'`gfx904`' Compile for GCN5 Vega gfx904 devices. (Experimental)

'`gfx906`' Compile for GCN5 Vega 20 devices (gfx906).

'`gfx908`' Compile for CDNA1 Instinct MI100 series devices (gfx908).

'`gfx909`' Compile for GCN5 Vega gfx909 devices. (Experimental)

'`gfx90a`' Compile for CDNA2 Instinct MI200 series devices (gfx90a).

'`gfx90c`' Compile for GCN5 Vega 7 devices (gfx90c).

'gfx942' Compile for CDNA3 Instinct MI300 series devices (gfx942). (Experimental)

'gfx950' Compile for the CDNA3 gfx950 devices. (Experimental)

'gfx9-generic'
: Compile generic code for Vega devices, executable on the following subset of GFX9 devices: gfx900, gfx902, gfx904, gfx906, gfx909 and gfx90c.

'gfx9-4-generic'
: Compile generic code for CDNA3 devices, executable on the following subset of GFX9 devices: gfx942 and gfx950. (Experimental)

'gfx1030' Compile for RDNA2 gfx1030 devices (GFX10 series).

'gfx1031' Compile for RDNA2 gfx1031 devices (GFX10 series). (Experimental)

'gfx1032' Compile for RDNA2 gfx1032 devices (GFX10 series). (Experimental)

'gfx1033' Compile for RDNA2 gfx1033 devices (GFX10 series). (Experimental)

'gfx1034' Compile for RDNA2 gfx1034 devices (GFX10 series). (Experimental)

'gfx1035' Compile for RDNA2 gfx1035 devices (GFX10 series). (Experimental)

'gfx1036' Compile for RDNA2 gfx1036 devices (GFX10 series).

'gfx10-3-generic'
: Compile generic code for GFX10-3 devices, executable on gfx1030, gfx1031, gfx1032, gfx1033, gfx1034, gfx1035, and gfx1036.

'gfx1100' Compile for RDNA3 gfx1100 devices (GFX11 series).

'gfx1101' Compile for RDNA3 gfx1101 devices (GFX11 series). (Experimental)

'gfx1102' Compile for RDNA3 gfx1102 devices (GFX11 series). (Experimental)

'gfx1103' Compile for RDNA3 gfx1103 devices (GFX11 series).

'gfx1150' Compile for RDNA3 gfx1150 devices (GFX11 series). (Experimental)

'gfx1151' Compile for RDNA3 gfx1151 devices (GFX11 series). (Experimental)

'gfx1152' Compile for RDNA3 gfx1152 devices (GFX11 series). (Experimental)

'gfx1153' Compile for RDNA3 gfx1153 devices (GFX11 series). (Experimental)

'gfx11-generic'
: Compile generic code for GFX11 devices, executable on gfx1100, gfx1101, gfx1102, gfx1103, gfx1150, gfx1151, gfx1152, and gfx1153.

-mgang-private-size=*bytes*
: Set the amount of local data-share (LDS) memory to reserve for gang-private variables. The default is 512.

-msram-ecc=on
-msram-ecc=off
-msram-ecc=any
: Compile binaries suitable for devices with the SRAM-ECC feature enabled, disabled, or either mode. This feature can be enabled per-process on some devices. The compiled code must match the device mode. The default is 'any', for devices that support it.

-mxnack=on
-mxnack=off
-mxnack=any
: Compile binaries suitable for devices with the XNACK feature enabled, disabled, or either mode. Some devices always require XNACK and some allow the user to configure XNACK. The compiled code must match the device mode. The default is '-mxnack=any' on devices that support Unified Shared Memory, and '-mxnack=no' otherwise.

-Wopenacc-dims
-Wno-openacc-dims
: Control warnings about invalid OpenACC dimensions.

3.20.4 ARC Options

The following options control the architecture variant for which code is being compiled:

-mbarrel-shifter
: Generate instructions supported by barrel shifter. This is the default unless -mcpu=ARC601 or '-mcpu=ARCEM' is in effect.

-mjli-always
: Force to call a function using jli_s instruction. This option is valid only for ARCv2 architecture.

-mcpu=*cpu*
: Set architecture type, register usage, and instruction scheduling parameters for *cpu*. There are also shortcut alias options available for backward compatibility and convenience. Supported values for *cpu* are

  'arc600' Compile for ARC600. Aliases: -mA6, -mARC600.

  'arc601' Compile for ARC601. Alias: -mARC601.

  'arc700' Compile for ARC700. Aliases: -mA7, -mARC700. This is the default when configured with --with-cpu=arc700.

  'arcem' Compile for ARC EM.

'archs' Compile for ARC HS.

'em' Compile for ARC EM CPU with no hardware extensions.

'em4' Compile for ARC EM4 CPU.

'em4_dmips'
: Compile for ARC EM4 DMIPS CPU.

'em4_fpus'
: Compile for ARC EM4 DMIPS CPU with the single-precision floating-point extension.

'em4_fpuda'
: Compile for ARC EM4 DMIPS CPU with single-precision floating-point and double assist instructions.

'hs' Compile for ARC HS CPU with no hardware extensions except the atomic instructions.

'hs34' Compile for ARC HS34 CPU.

'hs38' Compile for ARC HS38 CPU.

'hs38_linux'
: Compile for ARC HS38 CPU with all hardware extensions on.

'hs4x' Compile for ARC HS4x CPU.

'hs4xd' Compile for ARC HS4xD CPU.

'hs4x_rel31'
: Compile for ARC HS4x CPU release 3.10a.

'arc600_norm'
: Compile for ARC 600 CPU with `norm` instructions enabled.

'arc600_mul32x16'
: Compile for ARC 600 CPU with `norm` and 32x16-bit multiply instructions enabled.

'arc600_mul64'
: Compile for ARC 600 CPU with `norm` and `mul64`-family instructions enabled.

'arc601_norm'
: Compile for ARC 601 CPU with `norm` instructions enabled.

'arc601_mul32x16'
: Compile for ARC 601 CPU with `norm` and 32x16-bit multiply instructions enabled.

'arc601_mul64'
: Compile for ARC 601 CPU with `norm` and `mul64`-family instructions enabled.

'nps400' Compile for ARC 700 on NPS400 chip.

'em_mini' Compile for ARC EM minimalist configuration featuring reduced register set.

-mdpfp
-mdpfp-compact
Generate double-precision FPX instructions, tuned for the compact implementation.

-mdpfp-fast
Generate double-precision FPX instructions, tuned for the fast implementation.

-mno-dpfp-lrsr
Disable lr and sr instructions from using FPX extension aux registers.

-mea Generate extended arithmetic instructions. Currently only divaw, adds, subs, and sat16 are supported. Only valid for -mcpu=ARC700.

-mno-mpy Do not generate mpy-family instructions for ARC700. This option is deprecated.

-mmul32x16
Generate 32x16-bit multiply and multiply-accumulate instructions.

-mmul64 Generate mul64 and mulu64 instructions. Only valid for -mcpu=ARC600.

-mnorm Generate norm instructions. This is the default if -mcpu=ARC700 is in effect.

-mspfp
-mspfp-compact
Generate single-precision FPX instructions, tuned for the compact implementation.

-mspfp-fast
Generate single-precision FPX instructions, tuned for the fast implementation.

-msimd Enable generation of ARC SIMD instructions via target-specific builtins. Only valid for -mcpu=ARC700.

-msoft-float
This option ignored; it is provided for compatibility purposes only. Software floating-point code is emitted by default, and this default can overridden by FPX options; -mspfp, -mspfp-compact, or -mspfp-fast for single precision, and -mdpfp, -mdpfp-compact, or -mdpfp-fast for double precision.

-mswap Generate swap instructions.

-matomic This enables use of the locked load/store conditional extension to implement atomic memory built-in functions. Not available for ARC 6xx or ARC EM cores.

-mdiv-rem
Enable div and rem instructions for ARCv2 cores.

-mcode-density
Enable code density instructions for ARC EM. This option is on by default for ARC HS.

-mll64 Enable double load/store operations for ARC HS cores.

`-mtp-regno=`*regno*
: Specify thread pointer register number.

`-mmpy-option=`*multo*
: Compile ARCv2 code with a multiplier design option. You can specify the option using either a string or numeric value for *multo*. '`wlh1`' is the default value. The recognized values are:

  '`0`'
  '`none`' No multiplier available.

  '`1`'
  '`w`' 16x16 multiplier, fully pipelined. The following instructions are enabled: `mpyw` and `mpyuw`.

  '`2`'
  '`wlh1`' 32x32 multiplier, fully pipelined (1 stage). The following instructions are additionally enabled: `mpy`, `mpyu`, `mpym`, `mpymu`, and `mpy_s`.

  '`3`'
  '`wlh2`' 32x32 multiplier, fully pipelined (2 stages). The following instructions are additionally enabled: `mpy`, `mpyu`, `mpym`, `mpymu`, and `mpy_s`.

  '`4`'
  '`wlh3`' Two 16x16 multipliers, blocking, sequential. The following instructions are additionally enabled: `mpy`, `mpyu`, `mpym`, `mpymu`, and `mpy_s`.

  '`5`'
  '`wlh4`' One 16x16 multiplier, blocking, sequential. The following instructions are additionally enabled: `mpy`, `mpyu`, `mpym`, `mpymu`, and `mpy_s`.

  '`6`'
  '`wlh5`' One 32x4 multiplier, blocking, sequential. The following instructions are additionally enabled: `mpy`, `mpyu`, `mpym`, `mpymu`, and `mpy_s`.

  '`7`'
  '`plus_dmpy`'
  ARC HS SIMD support.

  '`8`'
  '`plus_macd`'
  ARC HS SIMD support.

  '`9`'
  '`plus_qmacw`'
  ARC HS SIMD support.

  This option is only available for ARCv2 cores.

`-mfpu=`*fpu*
: Enables support for specific floating-point hardware extensions for ARCv2 cores. Supported values for *fpu* are:

  '`fpus`' Enables support for single-precision floating-point hardware extensions.

'fpud' Enables support for double-precision floating-point hardware extensions. The single-precision floating-point extension is also enabled. Not available for ARC EM.

'fpuda' Enables support for double-precision floating-point hardware extensions using double-precision assist instructions. The single-precision floating-point extension is also enabled. This option is only available for ARC EM.

'fpuda_div'
Enables support for double-precision floating-point hardware extensions using double-precision assist instructions. The single-precision floating-point, square-root, and divide extensions are also enabled. This option is only available for ARC EM.

'fpuda_fma'
Enables support for double-precision floating-point hardware extensions using double-precision assist instructions. The single-precision floating-point and fused multiply and add hardware extensions are also enabled. This option is only available for ARC EM.

'fpuda_all'
Enables support for double-precision floating-point hardware extensions using double-precision assist instructions. All single-precision floating-point hardware extensions are also enabled. This option is only available for ARC EM.

'fpus_div'
Enables support for single-precision floating-point, square-root and divide hardware extensions.

'fpud_div'
Enables support for double-precision floating-point, square-root and divide hardware extensions. This option includes option 'fpus_div'. Not available for ARC EM.

'fpus_fma'
Enables support for single-precision floating-point and fused multiply and add hardware extensions.

'fpud_fma'
Enables support for double-precision floating-point and fused multiply and add hardware extensions. This option includes option 'fpus_fma'. Not available for ARC EM.

'fpus_all'
Enables support for all single-precision floating-point hardware extensions.

'fpud_all'
Enables support for all single- and double-precision floating-point hardware extensions. Not available for ARC EM.

`-mirq-ctrl-saved=register-range, blink, lp_count`
: Specifies general-purposes registers that the processor automatically saves/restores on interrupt entry and exit. *register-range* is specified as two registers separated by a dash. The register range always starts with `r0`, the upper limit is `fp` register. *blink* and *lp_count* are optional. This option is only valid for ARC EM and ARC HS cores.

`-mrgf-banked-regs=number`
: Specifies the number of registers replicated in second register bank on entry to fast interrupt. Fast interrupts are interrupts with the highest priority level P0. These interrupts save only PC and STATUS32 registers to avoid memory transactions during interrupt entry and exit sequences. Use this option when you are using fast interrupts in an ARC V2 family processor. Permitted values are 4, 8, 16, and 32.

`-mlpc-width=width`
: Specify the width of the `lp_count` register. Valid values for *width* are 8, 16, 20, 24, 28 and 32 bits. The default width is fixed to 32 bits. If the width is less than 32, the compiler does not attempt to transform loops in your program to use the zero-delay loop mechanism unless it is known that the `lp_count` register can hold the required loop-counter value. Depending on the width specified, the compiler and run-time library might continue to use the loop mechanism for various needs. This option defines macro `__ARC_LPC_WIDTH__` with the value of *width*.

`-mrf16`
: This option instructs the compiler to generate code for a 16-entry register file. This option defines the `__ARC_RF16__` preprocessor macro.

`-mbranch-index`
: Enable use of `bi` or `bih` instructions to implement jump tables.

The following options are passed through to the assembler, and also define preprocessor macro symbols.

`-mdsp-packa`
: Passed down to the assembler to enable the DSP Pack A extensions. Also sets the preprocessor symbol `__Xdsp_packa`. This option is deprecated.

`-mdvbf`
: Passed down to the assembler to enable the dual Viterbi butterfly extension. Also sets the preprocessor symbol `__Xdvbf`. This option is deprecated.

`-mlock`
: Passed down to the assembler to enable the locked load/store conditional extension. Also sets the preprocessor symbol `__Xlock`.

`-mmac-d16`
: Passed down to the assembler. Also sets the preprocessor symbol `__Xxmac_d16`. This option is deprecated.

`-mmac-24`
: Passed down to the assembler. Also sets the preprocessor symbol `__Xxmac_24`. This option is deprecated.

`-mrtsc`
: Passed down to the assembler to enable the 64-bit time-stamp counter extension instruction. Also sets the preprocessor symbol `__Xrtsc`. This option is deprecated.

`-mswape` Passed down to the assembler to enable the swap byte ordering extension instruction. Also sets the preprocessor symbol `__Xswape`.

`-mtelephony`
Passed down to the assembler to enable dual- and single-operand instructions for telephony. Also sets the preprocessor symbol `__Xtelephony`. This option is deprecated.

`-mxy` Passed down to the assembler to enable the XY memory extension. Also sets the preprocessor symbol `__Xxy`.

The following options control how the assembly code is annotated:

`-misize` Annotate assembler instructions with estimated addresses.

`-mannotate-align`
Does nothing. Preserved for backward compatibility.

The following options are passed through to the linker:

`-marclinux`
Passed through to the linker, to specify use of the `arclinux` emulation. This option is enabled by default in tool chains built for `arc-linux-uclibc` and `arceb-linux-uclibc` targets when profiling is not requested.

`-marclinux_prof`
Passed through to the linker, to specify use of the `arclinux_prof` emulation. This option is enabled by default in tool chains built for `arc-linux-uclibc` and `arceb-linux-uclibc` targets when profiling is requested.

The following options control the semantics of generated code:

`-mlong-calls`
Generate calls as register indirect calls, thus providing access to the full 32-bit address range.

`-mmedium-calls`
Don't use less than 25-bit addressing range for calls, which is the offset available for an unconditional branch-and-link instruction. Conditional execution of function calls is suppressed, to allow use of the 25-bit range, rather than the 21-bit range with conditional branch-and-link. This is the default for tool chains built for `arc-linux-uclibc` and `arceb-linux-uclibc` targets.

`-G` *num* Put definitions of externally-visible data in a small data section if that data is no bigger than *num* bytes. The default value of *num* is 4 for any ARC configuration, or 8 when we have double load/store operations.

`-mno-sdata`
Do not generate sdata references. This is the default for tool chains built for `arc-linux-uclibc` and `arceb-linux-uclibc` targets.

`-mvolatile-cache`
Use ordinarily cached memory accesses for volatile references. This is the default.

`-mno-volatile-cache`
: Enable cache bypass for volatile references.

The following options fine tune code generation:

`-malign-call`
: Does nothing. Preserved for backward compatibility.

`-mauto-modify-reg`
: Enable the use of pre/post modify with register displacement.

`-mbbit-peephole`
: Does nothing. Preserved for backward compatibility.

`-mno-brcc`
: This option disables a target-specific pass in `arc_reorg` to generate compare-and-branch (`brcc`) instructions. It has no effect on generation of these instructions driven by the combiner pass.

`-mcase-vector-pcrel`
: Use PC-relative switch case tables to enable case table shortening. This is the default for `-Os`.

`-mcompact-casesi`
: Enable compact `casesi` pattern. This is the default for `-Os`, and only available for ARCv1 cores. This option is deprecated.

`-mno-cond-exec`
: Disable the ARCompact-specific pass to generate conditional execution instructions.

  Due to delay slot scheduling and interactions between operand numbers, literal sizes, instruction lengths, and the support for conditional execution, the target-independent pass to generate conditional execution is often lacking, so the ARC port has kept a special pass around that tries to find more conditional execution generation opportunities after register allocation, branch shortening, and delay slot scheduling have been done. This pass generally, but not always, improves performance and code size, at the cost of extra compilation time, which is why there is an option to switch it off. If you have a problem with call instructions exceeding their allowable offset range because they are conditionalized, you should consider using `-mmedium-calls` instead.

`-mearly-cbranchsi`
: Enable pre-reload use of the `cbranchsi` pattern.

`-mexpand-adddi`
: Expand `adddi3` and `subdi3` at RTL generation time into `add.f`, `adc` etc. This option is deprecated.

`-mindexed-loads`
: Enable the use of indexed loads. This can be problematic because some optimizers then assume that indexed stores exist, which is not the case.

`-mlra`
: Does nothing. Preserved for backward compatibility.

`-mlra-priority-none`
: Don't indicate any priority for target registers.

`-mlra-priority-compact`
: Indicate target register priority for r0..r3 / r12..r15.

`-mlra-priority-noncompact`
: Reduce target register priority for r0..r3 / r12..r15.

`-mmillicode`
: When optimizing for size (using `-Os`), prologues and epilogues that have to save or restore a large number of registers are often shortened by using call to a special function in libgcc; this is referred to as a *millicode* call. As these calls can pose performance issues, and/or cause linking issues when linking in a nonstandard way, this option is provided to turn on or off millicode call generation.

`-mcode-density-frame`
: This option enable the compiler to emit `enter` and `leave` instructions. These instructions are only valid for CPUs with code-density feature.

`-mmixed-code`
: Does nothing. Preserved for backward compatibility.

`-mq-class`
: Ths option is deprecated. Enable '`q`' instruction alternatives. This is the default for `-Os`.

`-mRcq` Does nothing. Preserved for backward compatibility.

`-mRcw` Does nothing. Preserved for backward compatibility.

`-msize-level=`*`level`*
: Fine-tune size optimization with regards to instruction lengths and alignment. The recognized values for *level* are:

  '`0`' No size optimization. This level is deprecated and treated like '`1`'.

  '`1`' Short instructions are used opportunistically.

  '`2`' In addition, alignment of loops and of code after barriers are dropped.

  '`3`' In addition, optional data alignment is dropped, and the option `Os` is enabled.

  This defaults to '`3`' when `-Os` is in effect. Otherwise, the behavior when this is not set is equivalent to level '`1`'.

`-mtune=`*`cpu`*
: Set instruction scheduling parameters for *cpu*, overriding any implied by `-mcpu=`.

  Supported values for *cpu* are

  '`ARC600`' Tune for ARC600 CPU.

'ARC601' Tune for ARC601 CPU.

'ARC700' Tune for ARC700 CPU with standard multiplier block.

'ARC700-xmac'
Tune for ARC700 CPU with XMAC block.

'ARC725D' Tune for ARC725D CPU.

'ARC750D' Tune for ARC750D CPU.

'core3' Tune for ARCv2 core3 type CPU. This option enable usage of `dbnz` instruction.

'release31a'
Tune for ARC4x release 3.10a.

`-mmultcost=`*`num`*
Cost to assume for a multiply instruction, with '4' being equal to a normal instruction.

`-munalign-prob-threshold=`*`probability`*
Does nothing. Preserved for backward compatibility.

The following options are maintained for backward compatibility, but are now deprecated and will be removed in a future release:

`-margonaut`
Obsolete FPX.

`-mbig-endian`
`-EB` Compile code for big-endian targets. Use of these options is now deprecated. Big-endian code is supported by configuring GCC to build `arceb-elf32` and `arceb-linux-uclibc` targets, for which big endian is the default.

`-mlittle-endian`
`-EL` Compile code for little-endian targets. Use of these options is now deprecated. Little-endian code is supported by configuring GCC to build `arc-elf32` and `arc-linux-uclibc` targets, for which little endian is the default.

`-mbarrel_shifter`
Replaced by `-mbarrel-shifter`.

`-mdpfp_compact`
Replaced by `-mdpfp-compact`.

`-mdpfp_fast`
Replaced by `-mdpfp-fast`.

`-mdsp_packa`
Replaced by `-mdsp-packa`.

`-mEA` Replaced by `-mea`.

`-mmac_24` Replaced by `-mmac-24`.

`-mmac_d16`
Replaced by `-mmac-d16`.

`-mspfp_compact`
: Replaced by `-mspfp-compact`.

`-mspfp_fast`
: Replaced by `-mspfp-fast`.

`-mtune=`*cpu*
: Values '`arc600`', '`arc601`', '`arc700`' and '`arc700-xmac`' for *cpu* are replaced by '`ARC600`', '`ARC601`', '`ARC700`' and '`ARC700-xmac`' respectively.

`-multcost=`*num*
: Replaced by `-mmultcost`.

3.20.5 ARM Options

These '`-m`' options are defined for the ARM port:

`-mabi=`*name*
: Generate code for the specified ABI. Permissible values are: '`apcs-gnu`', '`atpcs`', '`aapcs`' and '`aapcs-linux`'.

`-mapcs-frame`
: Generate a stack frame that is compliant with the ARM Procedure Call Standard for all functions, even if this is not strictly necessary for correct execution of the code. Specifying `-fomit-frame-pointer` with this option causes the stack frames not to be generated for leaf functions. The default is `-mno-apcs-frame`. This option is deprecated.

`-mapcs`
: This is a synonym for `-mapcs-frame` and is deprecated.

`-mthumb-interwork`
: Generate code that supports calling between the ARM and Thumb instruction sets. Without this option, on pre-v5 architectures, the two instruction sets cannot be reliably used inside one program. The default is `-mno-thumb-interwork`, since slightly larger code is generated when `-mthumb-interwork` is specified. In AAPCS configurations this option is meaningless.

`-msched-prolog`
`-mno-sched-prolog`
: Allow or prevent the reordering of instructions in the function prologue, or the merging of those instruction with the instructions in the function's body. With `-mno-sched-prolog`, this means that all functions start with a recognizable set of instructions (or in fact one of a choice from a small set of different function prologues), and this information can be used to locate the start of functions inside an executable piece of code. The default is `-msched-prolog`.

`-mfloat-abi=`*name*
: Specifies which floating-point ABI to use. Permissible values are: '`soft`', '`softfp`' and '`hard`'.

  Specifying '`soft`' causes GCC to generate output containing library calls for floating-point operations. '`softfp`' allows the generation of code using hardware floating-point instructions, but still uses the soft-float calling conventions.

'hard' allows generation of floating-point instructions and uses FPU-specific calling conventions.

The default depends on the specific target configuration. Note that the hard-float and soft-float ABIs are not link-compatible; you must compile your entire program with the same ABI, and link with a compatible set of libraries.

`-mgeneral-regs-only`
: Generate code which uses only the general-purpose registers. This will prevent the compiler from using floating-point and Advanced SIMD registers but will not impose any restrictions on the assembler.

`-mlittle-endian`
: Generate code for a processor running in little-endian mode. This is the default for all standard configurations.

`-mbig-endian`
: Generate code for a processor running in big-endian mode; the default is to compile code for a little-endian processor.

`-mbe8`
`-mbe32`
: When linking a big-endian image select between BE8 and BE32 formats. The option has no effect for little-endian images and is ignored. The default is dependent on the selected target architecture. For ARMv6 and later architectures the default is BE8, for older architectures the default is BE32. BE32 format has been deprecated by ARM.

`-march=`*name*[`+extension...`]
: This specifies the name of the target ARM architecture. GCC uses this name to determine what kind of instructions it can emit when generating assembly code. This option can be used in conjunction with or instead of the `-mcpu=` option.

Permissible names are: 'armv4t', 'armv5t', 'armv5te', 'armv6', 'armv6j', 'armv6k', 'armv6kz', 'armv6t2', 'armv6z', 'armv6zk', 'armv7', 'armv7-a', 'armv7ve', 'armv8-a', 'armv8.1-a', 'armv8.2-a', 'armv8.3-a', 'armv8.4-a', 'armv8.5-a', 'armv8.6-a', 'armv9-a', 'armv7-r', 'armv8-r', 'armv6-m', 'armv6s-m', 'armv7-m', 'armv7e-m', 'armv8-m.base', 'armv8-m.main', 'armv8.1-m.main', 'iwmmxt' and 'iwmmxt2'.

Additionally, the following architectures, which lack support for the Thumb execution state, are recognized but support is deprecated: 'armv4'.

Many of the architectures support extensions. These can be added by appending '+*extension*' to the architecture name. Extension options are processed in order and capabilities accumulate. An extension will also enable any necessary base extensions upon which it depends. For example, the '+crypto' extension will always enable the '+simd' extension. The exception to the additive construction is for extensions that are prefixed with '+no...': these extensions disable the specified option and any other extensions that may depend on the presence of that extension.

For example, '-march=armv7-a+simd+nofp+vfpv4' is equivalent to writing '-march=armv7-a+vfpv4' since the '+simd' option is entirely disabled by the '+nofp' option that follows it.

Most extension names are generically named, but have an effect that is dependent upon the architecture to which it is applied. For example, the '+simd' option can be applied to both 'armv7-a' and 'armv8-a' architectures, but will enable the original ARMv7-A Advanced SIMD (Neon) extensions for 'armv7-a' and the ARMv8-A variant for 'armv8-a'.

The table below lists the supported extensions for each architecture. Architectures not mentioned do not support any extensions.

'armv5te'
'armv6'
'armv6j'
'armv6k'
'armv6kz'
'armv6t2'
'armv6z'
'armv6zk'

- '+fp' The VFPv2 floating-point instructions. The extension '+vfpv2' can be used as an alias for this extension.
- '+nofp' Disable the floating-point instructions.

'armv7' The common subset of the ARMv7-A, ARMv7-R and ARMv7-M architectures.

- '+fp' The VFPv3 floating-point instructions, with 16 double-precision registers. The extension '+vfpv3-d16' can be used as an alias for this extension. Note that floating-point is not supported by the base ARMv7-M architecture, but is compatible with both the ARMv7-A and ARMv7-R architectures.
- '+nofp' Disable the floating-point instructions.

'armv7-a'

- '+mp' The multiprocessing extension.
- '+sec' The security extension.
- '+fp' The VFPv3 floating-point instructions, with 16 double-precision registers. The extension '+vfpv3-d16' can be used as an alias for this extension.
- '+simd' The Advanced SIMD (Neon) v1 and the VFPv3 floating-point instructions. The extensions '+neon' and '+neon-vfpv3' can be used as aliases for this extension.
- '+vfpv3' The VFPv3 floating-point instructions, with 32 double-precision registers.

'+vfpv3-d16-fp16'
: The VFPv3 floating-point instructions, with 16 double-precision registers and the half-precision floating-point conversion operations.

'+vfpv3-fp16'
: The VFPv3 floating-point instructions, with 32 double-precision registers and the half-precision floating-point conversion operations.

'+vfpv4-d16'
: The VFPv4 floating-point instructions, with 16 double-precision registers.

'+vfpv4'
: The VFPv4 floating-point instructions, with 32 double-precision registers.

'+neon-fp16'
: The Advanced SIMD (Neon) v1 and the VFPv3 floating-point instructions, with the half-precision floating-point conversion operations.

'+neon-vfpv4'
: The Advanced SIMD (Neon) v2 and the VFPv4 floating-point instructions.

'+nosimd'
: Disable the Advanced SIMD instructions (does not disable floating point).

'+nofp'
: Disable the floating-point and Advanced SIMD instructions.

'armv7ve'
: The extended version of the ARMv7-A architecture with support for virtualization.

'+fp'
: The VFPv4 floating-point instructions, with 16 double-precision registers. The extension '+vfpv4-d16' can be used as an alias for this extension.

'+simd'
: The Advanced SIMD (Neon) v2 and the VFPv4 floating-point instructions. The extension '+neon-vfpv4' can be used as an alias for this extension.

'+vfpv3-d16'
: The VFPv3 floating-point instructions, with 16 double-precision registers.

'+vfpv3'
: The VFPv3 floating-point instructions, with 32 double-precision registers.

'+vfpv3-d16-fp16'
: The VFPv3 floating-point instructions, with 16 double-precision registers and the half-precision floating-point conversion operations.

'+vfpv3-fp16'
: The VFPv3 floating-point instructions, with 32 double-precision registers and the half-precision floating-point conversion operations.

'+vfpv4-d16'
: The VFPv4 floating-point instructions, with 16 double-precision registers.

'+vfpv4'
: The VFPv4 floating-point instructions, with 32 double-precision registers.

'+neon'
: The Advanced SIMD (Neon) v1 and the VFPv3 floating-point instructions. The extension '+neon-vfpv3' can be used as an alias for this extension.

'+neon-fp16'
: The Advanced SIMD (Neon) v1 and the VFPv3 floating-point instructions, with the half-precision floating-point conversion operations.

'+nosimd'
: Disable the Advanced SIMD instructions (does not disable floating point).

'+nofp'
: Disable the floating-point and Advanced SIMD instructions.

'armv8-a'

'+crc'
: The Cyclic Redundancy Check (CRC) instructions.

'+simd'
: The ARMv8-A Advanced SIMD and floating-point instructions.

'+crypto'
: The cryptographic instructions.

'+nocrypto'
: Disable the cryptographic instructions.

'+nofp'
: Disable the floating-point, Advanced SIMD and cryptographic instructions.

'+sb'
: Speculation Barrier Instruction.

'+predres'
: Execution and Data Prediction Restriction Instructions.

'armv8.1-a'

'+simd'
: The ARMv8.1-A Advanced SIMD and floating-point instructions.

'+crypto'
: The cryptographic instructions. This also enables the Advanced SIMD and floating-point instructions.

‘+nocrypto’
: Disable the cryptographic instructions.

‘+nofp’
: Disable the floating-point, Advanced SIMD and cryptographic instructions.

‘+sb’
: Speculation Barrier Instruction.

‘+predres’
: Execution and Data Prediction Restriction Instructions.

‘armv8.2-a’
‘armv8.3-a’

‘+fp16’
: The half-precision floating-point data processing instructions. This also enables the Advanced SIMD and floating-point instructions.

‘+fp16fml’
: The half-precision floating-point fmla extension. This also enables the half-precision floating-point extension and Advanced SIMD and floating-point instructions.

‘+simd’
: The ARMv8.1-A Advanced SIMD and floating-point instructions.

‘+crypto’
: The cryptographic instructions. This also enables the Advanced SIMD and floating-point instructions.

‘+dotprod’
: Enable the Dot Product extension. This also enables Advanced SIMD instructions.

‘+nocrypto’
: Disable the cryptographic extension.

‘+nofp’
: Disable the floating-point, Advanced SIMD and cryptographic instructions.

‘+sb’
: Speculation Barrier Instruction.

‘+predres’
: Execution and Data Prediction Restriction Instructions.

‘+i8mm’
: 8-bit Integer Matrix Multiply instructions. This also enables Advanced SIMD and floating-point instructions.

‘+bf16’
: Brain half-precision floating-point instructions. This also enables Advanced SIMD and floating-point instructions.

‘armv8.4-a’

‘+fp16’
: The half-precision floating-point data processing instructions. This also enables the Advanced SIMD

and floating-point instructions as well as the Dot Product extension and the half-precision floating-point fmla extension.

'+simd' The ARMv8.3-A Advanced SIMD and floating-point instructions as well as the Dot Product extension.

'+crypto' The cryptographic instructions. This also enables the Advanced SIMD and floating-point instructions as well as the Dot Product extension.

'+nocrypto'
Disable the cryptographic extension.

'+nofp' Disable the floating-point, Advanced SIMD and cryptographic instructions.

'+sb' Speculation Barrier Instruction.

'+predres'
Execution and Data Prediction Restriction Instructions.

'+i8mm' 8-bit Integer Matrix Multiply instructions. This also enables Advanced SIMD and floating-point instructions.

'+bf16' Brain half-precision floating-point instructions. This also enables Advanced SIMD and floating-point instructions.

'armv8.5-a'

'+fp16' The half-precision floating-point data processing instructions. This also enables the Advanced SIMD and floating-point instructions as well as the Dot Product extension and the half-precision floating-point fmla extension.

'+simd' The ARMv8.3-A Advanced SIMD and floating-point instructions as well as the Dot Product extension.

'+crypto' The cryptographic instructions. This also enables the Advanced SIMD and floating-point instructions as well as the Dot Product extension.

'+nocrypto'
Disable the cryptographic extension.

'+nofp' Disable the floating-point, Advanced SIMD and cryptographic instructions.

'+i8mm' 8-bit Integer Matrix Multiply instructions. This also enables Advanced SIMD and floating-point instructions.

'+bf16' Brain half-precision floating-point instructions. This also enables Advanced SIMD and floating-point instructions.

'armv8.6-a'

'+fp16' The half-precision floating-point data processing instructions. This also enables the Advanced SIMD and floating-point instructions as well as the Dot Product extension and the half-precision floating-point fmla extension.

'+simd' The ARMv8.3-A Advanced SIMD and floating-point instructions as well as the Dot Product extension.

'+crypto' The cryptographic instructions. This also enables the Advanced SIMD and floating-point instructions as well as the Dot Product extension.

'+nocrypto'
Disable the cryptographic extension.

'+nofp' Disable the floating-point, Advanced SIMD and cryptographic instructions.

'+i8mm' 8-bit Integer Matrix Multiply instructions. This also enables Advanced SIMD and floating-point instructions.

'+bf16' Brain half-precision floating-point instructions. This also enables Advanced SIMD and floating-point instructions.

'armv7-r'

'+fp.sp' The single-precision VFPv3 floating-point instructions. The extension '+vfpv3xd' can be used as an alias for this extension.

'+fp' The VFPv3 floating-point instructions with 16 double-precision registers. The extension +vfpv3-d16 can be used as an alias for this extension.

'+vfpv3xd-d16-fp16'
The single-precision VFPv3 floating-point instructions with 16 double-precision registers and the half-precision floating-point conversion operations.

'+vfpv3-d16-fp16'
The VFPv3 floating-point instructions with 16 double-precision registers and the half-precision floating-point conversion operations.

'+nofp' Disable the floating-point extension.

'+idiv' The ARM-state integer division instructions.

'+noidiv' Disable the ARM-state integer division extension.

'armv7e-m'

'+fp' The single-precision VFPv4 floating-point instructions.

'+fpv5' The single-precision FPv5 floating-point instructions.

'+fp.dp' The single- and double-precision FPv5 floating-point instructions.

'+nofp' Disable the floating-point extensions.

'armv8.1-m.main'

'+dsp' The DSP instructions.

'+mve' The M-Profile Vector Extension (MVE) integer instructions.

'+mve.fp' The M-Profile Vector Extension (MVE) integer and single precision floating-point instructions.

'+fp' The single-precision floating-point instructions.

'+fp.dp' The single- and double-precision floating-point instructions.

'+nofp' Disable the floating-point extension.

'+cdecp0, +cdecp1, ... , +cdecp7'
Enable the Custom Datapath Extension (CDE) on selected coprocessors according to the numbers given in the options in the range 0 to 7.

'+pacbti' Enable the Pointer Authentication and Branch Target Identification Extension.

'armv8-m.main'

'+dsp' The DSP instructions.

'+nodsp' Disable the DSP extension.

'+fp' The single-precision floating-point instructions.

'+fp.dp' The single- and double-precision floating-point instructions.

'+nofp' Disable the floating-point extension.

'+cdecp0, +cdecp1, ... , +cdecp7'
Enable the Custom Datapath Extension (CDE) on selected coprocessors according to the numbers given in the options in the range 0 to 7.

'armv8-r'

'+crc' The Cyclic Redundancy Check (CRC) instructions.

'+fp.sp' The single-precision FPv5 floating-point instructions.

'+simd' The ARMv8-A Advanced SIMD and floating-point instructions.

'+crypto' The cryptographic instructions.

'+nocrypto'
Disable the cryptographic instructions.

'+nofp' Disable the floating-point, Advanced SIMD and cryptographic instructions.

-march=native causes the compiler to auto-detect the architecture of the build computer. At present, this feature is only supported on GNU/Linux, and not all architectures are recognized. If the auto-detect is unsuccessful the option has no effect.

-march=unset causes the compiler to ignore any -march=... options that appear earlier on the command line and behave as if the option was never passed. This is useful to avoid warnings about conflicting CPU and architecture options when the two produce different architecture specifications.

-mtune=*name*

This option specifies the name of the target ARM processor for which GCC should tune the performance of the code. For some ARM implementations better performance can be obtained by using this option. Permissible names are: 'arm7tdmi', 'arm7tdmi-s', 'arm710t', 'arm720t', 'arm740t', 'strongarm', 'strongarm110', 'strongarm1100', 'strongarm1110', 'arm8', 'arm810', 'arm9', 'arm9e', 'arm920', 'arm920t', 'arm922t', 'arm946e-s', 'arm966e-s', 'arm968e-s', 'arm926ej-s', 'arm940t', 'arm9tdmi', 'arm10tdmi', 'arm1020t', 'arm1026ej-s', 'arm10e', 'arm1020e', 'arm1022e', 'arm1136j-s', 'arm1136jf-s', 'mpcore', 'mpcorenovfp', 'arm1156t2-s', 'arm1156t2f-s', 'arm1176jz-s', 'arm1176jzf-s', 'generic-armv7-a', 'cortex-a5', 'cortex-a7', 'cortex-a8', 'cortex-a9', 'cortex-a12', 'cortex-a15', 'cortex-a17', 'cortex-a32', 'cortex-a35', 'cortex-a53', 'cortex-a55', 'cortex-a57', 'cortex-a72', 'cortex-a73', 'cortex-a75', 'cortex-a76', 'cortex-a76ae', 'cortex-a77', 'cortex-a78', 'cortex-a78ae', 'cortex-a78c', 'cortex-a710', 'ares', 'cortex-r4', 'cortex-r4f', 'cortex-r5', 'cortex-r7', 'cortex-r8', 'cortex-r52', 'cortex-r52plus', 'cortex-m0', 'cortex-m0plus', 'cortex-m1', 'cortex-m3', 'cortex-m4', 'cortex-m7', 'cortex-m23', 'cortex-m33', 'cortex-m35p', 'cortex-m52', 'cortex-m55', 'cortex-m85', 'cortex-x1', 'cortex-x1c', 'cortex-m1.small-multiply', 'cortex-m0.small-multiply', 'cortex-m0plus.small-multiply', 'exynos-m1', 'marvell-pj4', 'neoverse-n1', 'neoverse-n2', 'neoverse-v1', 'xscale', 'iwmmxt', 'iwmmxt2', 'ep9312', 'fa526', 'fa626', 'fa606te', 'fa626te', 'fmp626', 'fa726te', 'star-mc1', 'xgene1'.

Additionally, this option can specify that GCC should tune the performance of the code for a big.LITTLE system. Permissible names are: 'cortex-a15.cortex-a7', 'cortex-a17.cortex-a7', 'cortex-a57.cortex-a53', 'cortex-a72.cortex-a53', 'cortex-a72.cortex-a35', 'cortex-a73.cortex-a53', 'cortex-a75.cortex-a55', 'cortex-a76.cortex-a55'.

`-mtune=generic-`*arch* specifies that GCC should tune the performance for a blend of processors within architecture *arch*. The aim is to generate code that run well on the current most popular processors, balancing between optimizations that benefit some CPUs in the range, and avoiding performance pitfalls of other CPUs. The effects of this option may change in future GCC versions as CPU models come and go.

`-mtune` permits the same extension options as `-mcpu`, but the extension options do not affect the tuning of the generated code.

`-mtune=native` causes the compiler to auto-detect the CPU of the build computer. At present, this feature is only supported on GNU/Linux, and not all architectures are recognized. If the auto-detect is unsuccessful the option has no effect.

`-mcpu=`*name*[`+extension...`]

This specifies the name of the target ARM processor. GCC uses this name to derive the name of the target ARM architecture (as if specified by `-march`) and the ARM processor type for which to tune for performance (as if specified by `-mtune`). Where this option is used in conjunction with `-march` or `-mtune`, those options take precedence over the appropriate part of this option.

Many of the supported CPUs implement optional architectural extensions. Where this is so the architectural extensions are normally enabled by default. If implementations that lack the extension exist, then the extension syntax can be used to disable those extensions that have been omitted. For floating-point and Advanced SIMD (Neon) instructions, the settings of the options `-mfloat-abi` and `-mfpu` must also be considered: floating-point and Advanced SIMD instructions will only be used if `-mfloat-abi` is not set to '`soft`'; and any setting of `-mfpu` other than '`auto`' will override the available floating-point and SIMD extension instructions.

For example, '`cortex-a9`' can be found in three major configurations: integer only, with just a floating-point unit or with floating-point and Advanced SIMD. The default is to enable all the instructions, but the extensions '`+nosimd`' and '`+nofp`' can be used to disable just the SIMD or both the SIMD and floating-point instructions respectively.

Permissible names for this option are the same as those for `-mtune`.

The following extension options are common to the listed CPUs:

'`+nodsp`' Disable the DSP instructions on '`cortex-m33`', '`cortex-m35p`', '`cortex-m52`', '`cortex-m55`' and '`cortex-m85`'. Also disable the M-Profile Vector Extension (MVE) integer and single precision floating-point instructions on '`cortex-m52`', '`cortex-m55`' and '`cortex-m85`'.

'`+nopacbti`'

Disable the Pointer Authentication and Branch Target Identification Extension on '`cortex-m52`' and '`cortex-m85`'.

'+nomve' Disable the M-Profile Vector Extension (MVE) integer and single precision floating-point instructions on 'cortex-m52', 'cortex-m55' and 'cortex-m85'.

'+nomve.fp'
Disable the M-Profile Vector Extension (MVE) single precision floating-point instructions on 'cortex-m52', 'cortex-m55' and 'cortex-m85'.

'+cdecp0, +cdecp1, ... , +cdecp7'
Enable the Custom Datapath Extension (CDE) on selected coprocessors according to the numbers given in the options in the range 0 to 7 on 'cortex-m52', 'cortex-m55' and 'star-mc1'.

'+nofp' Disables the floating-point instructions on 'arm9e', 'arm946e-s', 'arm966e-s', 'arm968e-s', 'arm10e', 'arm1020e', 'arm1022e', 'arm926ej-s', 'arm1026ej-s', 'cortex-r5', 'cortex-r7', 'cortex-r8', 'cortex-m4', 'cortex-m7', 'cortex-m33', 'cortex-m35p', 'cortex-m52', 'cortex-m55' and 'cortex-m85'. Disables the floating-point and SIMD instructions on 'generic-armv7-a', 'cortex-a5', 'cortex-a7', 'cortex-a8', 'cortex-a9', 'cortex-a12', 'cortex-a15', 'cortex-a17', 'cortex-a15.cortex-a7', 'cortex-a17.cortex-a7', 'cortex-a32', 'cortex-a35', 'cortex-a53' and 'cortex-a55'.

'+nofp.dp'
Disables the double-precision component of the floating-point instructions on 'cortex-r5', 'cortex-r7', 'cortex-r8', 'cortex-r52', 'cortex-r52plus' and 'cortex-m7'.

'+nosimd' Disables the SIMD (but not floating-point) instructions on 'generic-armv7-a', 'cortex-a5', 'cortex-a7' and 'cortex-a9'.

'+crypto' Enables the cryptographic instructions on 'cortex-a32', 'cortex-a35', 'cortex-a53', 'cortex-a55', 'cortex-a57', 'cortex-a72', 'cortex-a73', 'cortex-a75', 'exynos-m1', 'xgene1', 'cortex-a57.cortex-a53', 'cortex-a72.cortex-a53', 'cortex-a73.cortex-a35', 'cortex-a73.cortex-a53' and 'cortex-a75.cortex-a55'.

Additionally the 'generic-armv7-a' pseudo target defaults to VFPv3 with 16 double-precision registers. It supports the following extension options: 'mp', 'sec', 'vfpv3-d16', 'vfpv3', 'vfpv3-d16-fp16', 'vfpv3-fp16', 'vfpv4-d16', 'vfpv4', 'neon', 'neon-vfpv3', 'neon-fp16', 'neon-vfpv4'. The meanings are the same as for the extensions to -march=armv7-a.

-mcpu=generic-*arch* is also permissible, and is equivalent to -march=*arch* -mtune=generic-*arch*. See -mtune for more information.

-mcpu=native causes the compiler to auto-detect the CPU of the build computer. At present, this feature is only supported on GNU/Linux, and not all architectures are recognized. If the auto-detect is unsuccessful the option has no effect.

-mcpu=unset causes the compiler to ignore any -mcpu=... options that appear earlier on the command line and behave as if the option was never passed. This is useful to avoid warnings about conflicting CPU and architecture options when the two produce different architecture specifications.

-mfpu=*name*
: This specifies what floating-point hardware (or hardware emulation) is available on the target. Permissible names are: 'auto', 'vfpv2', 'vfpv3', 'vfpv3-fp16', 'vfpv3-d16', 'vfpv3-d16-fp16', 'vfpv3xd', 'vfpv3xd-fp16', 'neon-vfpv3', 'neon-fp16', 'vfpv4', 'vfpv4-d16', 'fpv4-sp-d16', 'neon-vfpv4', 'fpv5-d16', 'fpv5-sp-d16', 'fp-armv8', 'neon-fp-armv8' and 'crypto-neon-fp-armv8'. Note that 'neon' is an alias for 'neon-vfpv3' and 'vfp' is an alias for 'vfpv2'.

The setting 'auto' is the default and is special. It causes the compiler to select the floating-point and Advanced SIMD instructions based on the settings of -mcpu and -march.

If the selected floating-point hardware includes the NEON extension (e.g. -mfpu=neon), note that floating-point operations are not generated by GCC's auto-vectorization pass unless -funsafe-math-optimizations is also specified. This is because NEON hardware does not fully implement the IEEE 754 standard for floating-point arithmetic (in particular denormal values are treated as zero), so the use of NEON instructions may lead to a loss of precision.

You can also set the fpu name at function level by using the target("fpu=") function attributes (see Section 6.4.1.5 [ARM Function Attributes], page 657) or pragmas (see Section 6.5.16 [Function Specific Option Pragmas], page 745).

-mfp16-format=*name*
: Specify the format of the __fp16 half-precision floating-point type. Permissible names are 'none', 'ieee', and 'alternative'; the default is 'none', in which case the __fp16 type is not defined. See Section 6.1.5 [Half-Precision], page 606, for more information.

-mstructure-size-boundary=*n*
: The sizes of all structures and unions are rounded up to a multiple of the number of bits set by this option. Permissible values are 8, 32 and 64. The default value varies for different toolchains. For the COFF targeted toolchain the default value is 8. A value of 64 is only allowed if the underlying ABI supports it.

Specifying a larger number can produce faster, more efficient code, but can also increase the size of the program. Different values are potentially incompatible. Code compiled with one value cannot necessarily expect to work with code or libraries compiled with another value, if they exchange information using structures or unions.

This option is deprecated.

-mabort-on-noreturn
: Generate a call to the function abort at the end of a noreturn function. It is executed if the function tries to return.

`-mlong-calls`
`-mno-long-calls`

Tells the compiler to perform function calls by first loading the address of the function into a register and then performing a subroutine call on this register. This switch is needed if the target function lies outside of the 64-megabyte addressing range of the offset-based version of subroutine call instruction.

Even if this switch is enabled, not all function calls are turned into long calls. The heuristic is that static functions, functions that have the `short_call` attribute, functions that are inside the scope of a `#pragma no_long_calls` directive, and functions whose definitions have already been compiled within the current compilation unit are not turned into long calls. The exceptions to this rule are that weak function definitions, functions with the `long_call` attribute or the `section` attribute, and functions that are within the scope of a `#pragma long_calls` directive are always turned into long calls.

This feature is not enabled by default. Specifying `-mno-long-calls` restores the default behavior, as does placing the function calls within the scope of a `#pragma long_calls_off` directive. Note these switches have no effect on how the compiler generates code to handle function calls via function pointers.

`-msingle-pic-base`

Treat the register used for PIC addressing as read-only, rather than loading it in the prologue for each function. The runtime system is responsible for initializing this register with an appropriate value before execution begins.

`-mpic-register=`*reg*

Specify the register to be used for PIC addressing. For standard PIC base case, the default is any suitable register determined by compiler. For single PIC base case, the default is '`R9`' if target is EABI based or stack-checking is enabled, otherwise the default is '`R10`'.

`-mpic-data-is-text-relative`

Assume that the displacement between the text and data segments is fixed at static link time. This permits using PC-relative addressing operations to access data known to be in the data segment. For non-VxWorks RTP targets, this option is enabled by default. When disabled on such targets, it will enable `-msingle-pic-base` by default.

`-mpoke-function-name`

Write the name of each function into the text section, directly preceding the function prologue. The generated code is similar to this:

```
t0
    .ascii "arm_poke_function_name", 0
    .align
t1
    .word 0xff000000 + (t1 - t0)
arm_poke_function_name
    mov     ip, sp
    stmfd   sp!, {fp, ip, lr, pc}
    sub     fp, ip, #4
```

When performing a stack backtrace, code can inspect the value of `pc` stored at `fp + 0`. If the trace function then looks at location `pc - 12` and the top 8 bits are set, then we know that there is a function name embedded immediately preceding this location and has length `((pc[-3]) & 0xff000000)`.

`-mthumb`
`-marm`
Select between generating code that executes in ARM and Thumb states. The default for most configurations is to generate code that executes in ARM state, but the default can be changed by configuring GCC with the `--with-mode=`*state* configure option.

You can also override the ARM and Thumb mode for each function by using the `target("thumb")` and `target("arm")` function attributes (see Section 6.4.1.5 [ARM Function Attributes], page 657) or pragmas (see Section 6.5.16 [Function Specific Option Pragmas], page 745).

`-mtpcs-frame`
Generate a stack frame that is compliant with the Thumb Procedure Call Standard for all non-leaf functions. (A leaf function is one that does not call any other functions.) The default is `-mno-tpcs-frame`.

`-mtpcs-leaf-frame`
Generate a stack frame that is compliant with the Thumb Procedure Call Standard for all leaf functions. (A leaf function is one that does not call any other functions.) The default is `-mno-apcs-leaf-frame`.

`-mcallee-super-interworking`
Gives all externally visible functions in the file being compiled an ARM instruction set header which switches to Thumb mode before executing the rest of the function. This allows these functions to be called from non-interworking code. This option is not valid in AAPCS configurations because interworking is enabled by default.

`-mcaller-super-interworking`
Allows calls via function pointers (including virtual functions) to execute correctly regardless of whether the target code has been compiled for interworking or not. There is a small overhead in the cost of executing a function pointer if this option is enabled. This option is not valid in AAPCS configurations because interworking is enabled by default.

`-mtp=`*name*
Specify the access model for the thread local storage pointer. The model '`soft`' generates calls to `__aeabi_read_tp`. Other accepted models are '`tpidrurw`', '`tpidruro`' and '`tpidrprw`' which fetch the thread pointer from the corresponding system register directly (supported from the arm6k architecture and later). These system registers are accessed through the CP15 co-processor interface and the argument '`cp15`' is also accepted as a convenience alias of '`tpidruro`'. The argument '`auto`' uses the best available method for the selected processor. The default setting is '`auto`'.

`-mtls-dialect=`*dialect*
Specify the dialect to use for accessing thread local storage. Two *dialects* are supported—'`gnu`' and '`gnu2`'. The '`gnu`' dialect selects the original GNU scheme

for supporting local and global dynamic TLS models. The 'gnu2' dialect selects the GNU descriptor scheme, which provides better performance for shared libraries. The GNU descriptor scheme is compatible with the original scheme, but does require new assembler, linker and library support. Initial and local exec TLS models are unaffected by this option and always use the original scheme.

`-mword-relocations`
: Only generate absolute relocations on word-sized values (i.e. R_ARM_ABS32). This is enabled by default on targets (uClinux, SymbianOS) where the runtime loader imposes this restriction, and when `-fpic` or `-fPIC` is specified. This option conflicts with `-mslow-flash-data`.

`-mfix-cortex-m3-ldrd`
: Some Cortex-M3 cores can cause data corruption when `ldrd` instructions with overlapping destination and base registers are used. This option avoids generating these instructions. This option is enabled by default when `-mcpu=cortex-m3` is specified.

`-mfix-cortex-a57-aes-1742098`
`-mno-fix-cortex-a57-aes-1742098`
`-mfix-cortex-a72-aes-1655431`
`-mno-fix-cortex-a72-aes-1655431`
: Enable (disable) mitigation for an erratum on Cortex-A57 and Cortex-A72 that affects the AES cryptographic instructions. This option is enabled by default when either `-mcpu=cortex-a57` or `-mcpu=cortex-a72` is specified.

`-munaligned-access`
`-mno-unaligned-access`
: Enables (or disables) reading and writing of 16- and 32- bit values from addresses that are not 16- or 32- bit aligned. By default unaligned access is disabled for all pre-ARMv6, all ARMv6-M and for ARMv8-M Baseline architectures, and enabled for all other architectures. If unaligned access is not enabled then words in packed data structures are accessed a byte at a time.

  The ARM attribute `Tag_CPU_unaligned_access` is set in the generated object file to either true or false, depending upon the setting of this option. If unaligned access is enabled then the preprocessor symbol `__ARM_FEATURE_UNALIGNED` is also defined.

`-mslow-flash-data`
: Assume loading data from flash is slower than fetching instruction. Therefore literal load is minimized for better performance. This option is only supported when compiling for ARMv7 M-profile and off by default. It conflicts with `-mword-relocations`.

`-masm-syntax-unified`
: Assume inline assembler is using unified asm syntax. The default is currently off which implies divided syntax. This option has no impact on Thumb2. However, this may change in future releases of GCC. Divided syntax should be considered deprecated.

`-mrestrict-it`
: Restricts generation of IT blocks to conform to the rules of ARMv8-A. IT blocks can only contain a single 16-bit instruction from a select set of instructions. This option is on by default for ARMv8-A Thumb mode.

`-mpure-code`
: Do not allow constant data to be placed in code sections. Additionally, when compiling for ELF object format give all text sections the ELF processor-specific section attribute `SHF_ARM_PURECODE`. This option is only available when generating non-pic code for M-profile targets.

`-mcmse`
: Generate secure code as per the "ARMv8-M Security Extensions: Requirements on Development Tools Engineering Specification", which can be found on `https://developer.arm.com/documentation/ecm0359818/latest/`.

`-mfix-cmse-cve-2021-35465`
: Mitigate against a potential security issue with the `VLLDM` instruction in some M-profile devices when using CMSE (CVE-2021-365465). This option is enabled by default when the option `-mcpu=` is used with `cortex-m33`, `cortex-m35p`, `cortex-m52`, `cortex-m55`, `cortex-m85` or `star-mc1`. The option `-mno-fix-cmse-cve-2021-35465` can be used to disable the mitigation.

`-mstack-protector-guard=`*`guard`*
`-mstack-protector-guard-offset=`*`offset`*
: Generate stack protection code using canary at *guard*. Supported locations are '`global`' for a global canary or '`tls`' for a canary accessible via the TLS register. The option `-mstack-protector-guard-offset=` is for use with `-fstack-protector-guard=tls` and not for use in user-land code.

`-mfdpic`
`-mno-fdpic`
: Select the FDPIC ABI, which uses 64-bit function descriptors to represent pointers to functions. When the compiler is configured for `arm-*-uclinuxfdpiceabi` targets, this option is on by default and implies `-fPIE` if none of the PIC/PIE-related options is provided. On other targets, it only enables the FDPIC-specific code generation features, and the user should explicitly provide the PIC/PIE-related options as needed.

  Note that static linking is not supported because it would still involve the dynamic linker when the program self-relocates. If such behavior is acceptable, use -static and -Wl,-dynamic-linker options.

  The opposite `-mno-fdpic` option is useful (and required) to build the Linux kernel using the same (`arm-*-uclinuxfdpiceabi`) toolchain as the one used to build the userland programs.

`-mbranch-protection=`*`features`*
: Enable branch protection features (armv8.1-m.main only).

  features can have one of the following forms:

  '`none`' generates code without branch protection or return address signing.

  '`standard`' generates code with all branch protection features enabled at their standard level.

'`pac-ret`' generates code with return address signing set to its standard level, which is to sign all functions that save the return address to memory.

'`pac-ret+leaf`' extends the '`pac-ret`' signing to include leaf functions even if they do not write the return address to memory.

'`bti`' adds landing-pad instructions at the permitted targets of indirect branch instructions.

If support for the '`+pacbti`' architecture extension is not enabled (e.g. via `-march=`), then all branch protection and return address signing operations are constrained to use only the instructions defined in the architectural-NOP space. The generated code remains backwards-compatible with earlier versions of the architecture, but the additional security can be enabled at run time on processors that support the '`PACBTI`' extension.

Branch target enforcement using BTI can only be enabled at runtime if all code in the application has been compiled with at least '`-mbranch-protection=bti`'.

Any setting other than '`none`' is supported only on armv8-m.main or later.

The default is to generate code without branch protection or return address signing.

3.20.6 AVR Options

These options are defined for AVR implementations:

`-mmcu=`*mcu*

Specify the AVR instruction set architecture (ISA) or device type. The default for this option is `avr2`.

The following AVR devices and ISAs are supported. *Note:* A complete device support consists of startup code `crt`*mcu*`.o`, a device header `avr/io*.h`, a device library `lib`*mcu*`.a` and a device-specs (`https://gcc.gnu.org/wiki/avr-gcc#spec-files`) file `specs-`*mcu*. Only the latter is provided by the compiler according the supported *mcu*s below. The rest is supported by AVR-LibC (`https://github.com/avrdudes/avr-libc/`), or by means of `atpack` (`https://gcc.gnu.org/wiki/avr-gcc#atpack`) files from the hardware manufacturer.

`avr2` "Classic" devices with up to 8 KiB of program memory.
mcu = `attiny22`, `attiny26`, `at90s2313`, `at90s2323`, `at90s2333`, `at90s2343`, `at90s4414`, `at90s4433`, `at90s4434`, `at90c8534`, `at90s8515`, `at90s8535`.

`avr25` "Classic" devices with up to 8 KiB of program memory and with the `MOVW` instruction.
mcu = `attiny13`, `attiny13a`, `attiny24`, `attiny24a`, `attiny25`, `attiny261`, `attiny261a`, `attiny2313`, `attiny2313a`, `attiny43u`, `attiny44`, `attiny44a`, `attiny45`, `attiny48`, `attiny441`, `attiny461`, `attiny461a`, `attiny4313`, `attiny84`, `attiny84a`, `attiny85`, `attiny87`, `attiny88`, `attiny828`, `attiny841`, `attiny861`, `attiny861a`, `ata5272`, `ata6616c`, `at86rf401`.

`avr3` "Classic" devices with 16 KiB up to 64 KiB of program memory.
mcu = `at76c711`, `at43usb355`.

`avr31` "Classic" devices with 128 KiB of program memory.
mcu = `atmega103`, `at43usb320`.

`avr35` "Classic" devices with 16 KiB up to 64 KiB of program memory and with the `MOVW` instruction.
mcu = `attiny167`, `attiny1634`, `atmega8u2`, `atmega16u2`, `atmega32u2`, `ata5505`, `ata6617c`, `ata664251`, `at90usb82`, `at90usb162`.

`avr4` "Enhanced" devices with up to 8 KiB of program memory.
mcu = `atmega48`, `atmega48a`, `atmega48p`, `atmega48pa`, `atmega48pb`, `atmega8`, `atmega8a`, `atmega8hva`, `atmega88`, `atmega88a`, `atmega88p`, `atmega88pa`, `atmega88pb`, `atmega8515`, `atmega8535`, `ata5795`, `ata6285`, `ata6286`, `ata6289`, `ata6612c`, `at90pwm1`, `at90pwm2`, `at90pwm2b`, `at90pwm3`, `at90pwm3b`, `at90pwm81`.

`avr5` "Enhanced" devices with 16 KiB up to 64 KiB of program memory.
mcu = `atmega16`, `atmega16a`, `atmega16hva`, `atmega16hva2`, `atmega16hvb`, `atmega16hvbrevb`, `atmega16m1`, `atmega16u4`, `atmega161`, `atmega162`, `atmega163`, `atmega164a`, `atmega164p`, `atmega164pa`, `atmega165`, `atmega165a`, `atmega165p`, `atmega165pa`, `atmega168`, `atmega168a`, `atmega168p`, `atmega168pa`, `atmega168pb`, `atmega169`, `atmega169a`, `atmega169p`, `atmega169pa`, `atmega32`, `atmega32a`, `atmega32c1`, `atmega32hvb`, `atmega32hvbrevb`, `atmega32m1`, `atmega32u4`, `atmega32u6`, `atmega323`, `atmega324a`, `atmega324p`, `atmega324pa`, `atmega324pb`, `atmega325`, `atmega325a`, `atmega325p`, `atmega325pa`, `atmega328`, `atmega328p`, `atmega328pb`, `atmega329`, `atmega329a`, `atmega329p`, `atmega329pa`, `atmega3250`, `atmega3250a`, `atmega3250p`, `atmega3250pa`, `atmega3290`, `atmega3290a`, `atmega3290p`, `atmega3290pa`, `atmega406`, `atmega64`, `atmega64a`, `atmega64c1`, `atmega64hve`, `atmega64hve2`, `atmega64m1`, `atmega64rfr2`, `atmega640`, `atmega644`, `atmega644a`, `atmega644p`, `atmega644pa`, `atmega644rfr2`, `atmega645`, `atmega645a`, `atmega645p`, `atmega649`, `atmega649a`, `atmega649p`, `atmega6450`, `atmega6450a`, `atmega6450p`, `atmega6490`, `atmega6490a`, `atmega6490p`, `ata5790`, `ata5790n`, `ata5791`, `ata6613c`, `ata6614q`, `ata5782`, `ata5831`, `ata8210`, `ata8510`, `ata5787`, `ata5835`, `ata5700m322`, `ata5702m322`, `at90pwm161`, `at90pwm216`, `at90pwm316`, `at90can32`, `at90can64`, `at90scr100`, `at90usb646`, `at90usb647`, `at94k`, `m3000`.

`avr51` "Enhanced" devices with 128 KiB of program memory.
mcu = `atmega128`, `atmega128a`, `atmega128rfa1`, `atmega128rfr2`,

atmega1280, atmega1281, atmega1284, atmega1284p, atmega1284rfr2, at90can128, at90usb1286, at90usb1287.

avr6
"Enhanced" devices with 3-byte PC, i.e. with more than 128 KiB of program memory.
mcu = atmega256rfr2, atmega2560, atmega2561, atmega2564rfr2.

avrxmega2
"XMEGA" devices with more than 8 KiB and up to 64 KiB of program memory.
mcu = atxmega8e5, atxmega16a4, atxmega16a4u, atxmega16c4, atxmega16d4, atxmega16e5, atxmega32a4, atxmega32a4u, atxmega32c3, atxmega32c4, atxmega32d3, atxmega32d4, atxmega32e5, avr64da28, avr64da28s, avr64da32, avr64da32s, avr64da48, avr64da48s, avr64da64, avr64da64s, avr64db28, avr64db32, avr64db48, avr64db64, avr64dd14, avr64dd20, avr64dd28, avr64dd32, avr64du28, avr64du32, avr64ea28, avr64ea32, avr64ea48, avr64sd28, avr64sd32, avr64sd48.

avrxmega3
"XMEGA" devices with up to 64 KiB of combined program memory and RAM, and with program memory visible in the RAM address space.
mcu = attiny202, attiny204, attiny212, attiny214, attiny402, attiny404, attiny406, attiny412, attiny414, attiny416, attiny416auto, attiny417, attiny424, attiny426, attiny427, attiny804, attiny806, attiny807, attiny814, attiny816, attiny817, attiny824, attiny826, attiny827, attiny1604, attiny1606, attiny1607, attiny1614, attiny1616, attiny1617, attiny1624, attiny1626, attiny1627, attiny3214, attiny3216, attiny3217, attiny3224, attiny3226, attiny3227, atmega808, atmega809, atmega1608, atmega1609, atmega3208, atmega3209, atmega4808, atmega4809, avr16dd14, avr16dd20, avr16dd28, avr16dd32, avr16du14, avr16du20, avr16du28, avr16du32, avr16ea28, avr16ea32, avr16ea48, avr16eb14, avr16eb20, avr16eb28, avr16eb32, avr16la14, avr16la20, avr16la28, avr16la32, avr32da28, avr32da28s, avr32da32, avr32da32s, avr32da48, avr32da48s, avr32db28, avr32db32, avr32db48, avr32dd14, avr32dd20, avr32dd28, avr32dd32, avr32du14, avr32du20, avr32du28, avr32du32, avr32ea28, avr32ea32, avr32ea48, avr32eb14, avr32eb20, avr32eb28, avr32eb32, avr32la14, avr32la20, avr32la28, avr32la32, avr32sd20, avr32sd28, avr32sd32.

avrxmega4
"XMEGA" devices with more than 64 KiB and up to 128 KiB of program memory.
mcu = atxmega64a3, atxmega64a3u, atxmega64a4u,

atxmega64b1, atxmega64b3, atxmega64c3, atxmega64d3, atxmega64d4, avr128da28, avr128da28s, avr128da32, avr128da32s, avr128da48, avr128da48s, avr128da64, avr128da64s, avr128db28, avr128db32, avr128db48, avr128db64.

`avrxmega5`
: "XMEGA" devices with more than 64 KiB and up to 128 KiB of program memory and more than 64 KiB of RAM.
mcu = atxmega64a1, atxmega64a1u.

`avrxmega6`
: "XMEGA" devices with more than 128 KiB of program memory.
mcu = atxmega128a3, atxmega128a3u, atxmega128b1, atxmega128b3, atxmega128c3, atxmega128d3, atxmega128d4, atxmega192a3, atxmega192a3u, atxmega192c3, atxmega192d3, atxmega256a3, atxmega256a3b, atxmega256a3bu, atxmega256a3u, atxmega256c3, atxmega256d3, atxmega384c3, atxmega384d3.

`avrxmega7`
: "XMEGA" devices with more than 128 KiB of program memory and more than 64 KiB of RAM.
mcu = atxmega128a1, atxmega128a1u, atxmega128a4u.

`avrtiny`
: "Reduced Tiny" Tiny core devices with only 16 general purpose registers and 512 B up to 4 KiB of program memory.
mcu = attiny4, attiny5, attiny9, attiny10, attiny102, attiny104, attiny20, attiny40.

`avr1`
: This ISA is implemented by the minimal AVR core and supported for assembler only.
mcu = attiny11, attiny12, attiny15, attiny28, at90s1200.

`-mabsdata`
: Assume that all data in static storage can be accessed by LDS / STS instructions. This option has only an effect on reduced Tiny devices like ATtiny40. See also the `absdata` Section 6.4.2.3 [AVR Variable Attributes], page 709.

`-mcvt`
: Use a *compact vector table*. Some devices support a CVT with only four entries: 0=Reset, 1=NMI, 2=Prio1 IRQ, 3=Prio0 IRQs. This option will link startup code from `crtmcu-cvt.o` instead of the usual `crtmcu.o`. Apart from providing a compact vector table, the startup code will set bit `CPUINT_CTRLA.CPUINT_CVT` which enables the CVT on the device.

When you do not want the startup code to set `CPUINT_CTRLA.CPUINT_CVT`, then you can satisfy symbol `__init_cvt` so that the respective code is no more pulled in from `libmcu.a`. For example, you can link with `-Wl,--defsym,__init_cvt=0`.

The CVT startup code is available since AVR-LibC v2.3 (`https://github.com/avrdudes/avr-libc/issues/1010`).

`-mdouble=bits`
`-mlong-double=bits`
: Set the size (in bits) of the `double` or `long double` type, respectively. Possible values for *bits* are 32 and 64. Whether or not a specific value for *bits* is allowed depends on the `--with-double=` and `--with-long-double=` configure options (`https://gcc.gnu.org/install/configure.html#avr`), and the same applies for the default values of the options.

`-mgas-isr-prologues`
: Interrupt service routines (ISRs) may use the `__gcc_isr` pseudo instruction supported by GNU Binutils. If this option is on, the feature can still be disabled for individual ISRs by means of the Section 6.4.1.6 [`no_gccisr`], page 659, function attribute. This feature is activated per default if optimization is on (but not with `-Og`, see Section 3.12 [Optimize Options], page 194), and if GNU Binutils support PR21683 (`https://sourceware.org/PR21683`).

`-mint8`
: Assume `int` to be 8-bit integer. This affects the sizes of all types: a `char` is 1 byte, an `int` is 1 byte, a `long` is 2 bytes, and `long long` is 4 bytes. Please note that this option does not conform to the C standards, but it results in smaller code size.

`-mmain-is-OS_task`
: Do not save registers in `main`. The effect is the same like attaching attribute Section 6.4.1.6 [`OS_task`], page 659, to `main`. It is activated per default if optimization is on.

`-mno-call-main`
: Don't run `main` by means of

```
XCALL  main
XJMP   exit
```

Instead, put `main` in section `.init9` (`https://avrdudes.github.io/avr-libc/avr-libc-user-manual/mem_sections.html#sec_dot_init`) so that no call is required. By setting this option the user asserts that `main` will not return.

This option can be used for devices with very limited resources in order to save a few bytes of code and stack space. It will work as expected since AVR-LibC v2.3 (`https://github.com/avrdudes/avr-libc/issues/1012`). With older versions, there will be no performance gain.

`-mno-interrupts`
: Generated code is not compatible with hardware interrupts. Code size is smaller.

`-mrelax`
: Try to replace `CALL` resp. `JMP` instruction by the shorter `RCALL` resp. `RJMP` instruction if applicable. Setting `-mrelax` just adds the `--mlink-relax` option to the assembler's command line and the `--relax` option to the linker's command line.

Jump relaxing is performed by the linker because jump offsets are not known before code is located. Therefore, the assembler code generated by the compiler is the same, but the instructions in the executable may differ from instructions in the assembler code.

Relaxing must be turned on if linker stubs are needed, see the section on `EIND` and linker stubs below.

`-mrodata-in-ram`
`-mno-rodata-in-ram`

Locate the `.rodata` sections for read-only data in RAM resp. in program memory. For most devices, there is no choice and this option acts rather like an assertion.

Since v14 and for the AVR64* and AVR128* devices, `.rodata` is located in flash memory per default, provided the required GNU Binutils support (PR31124 (`https://sourceware.org/PR31124`)) is available. In that case, `-mrodata-in-ram` can be used to return to the old layout with `.rodata` in RAM.

`-mtiny-stack`

Only change the lower 8 bits of the stack pointer.

`-mfract-convert-truncate`

Allow to use truncation instead of rounding towards zero for fractional fixed-point types.

`-nodevicelib`

Don't link against AVR-LibC's device specific library `lib`*`mcu`*`.a`.

Notice that since AVR-LibC v2.3, that library contains code that is essential for the correct functioning of a program. In particular, it contains parts of the startup code like: `__init_sp` (`https://github.com/avrdudes/avr-libc/issues/1011`) to initialize the stack pointer with symbol `__stack`, `__init_cvt` (`https://github.com/avrdudes/avr-libc/issues/1010`) to set up the hardware to use a compact vector table with `-mcvt`, `__call_main` (`https://github.com/avrdudes/avr-libc/issues/1012`) to call `main` and `exit`, and `__do_flmap_init` (`https://github.com/avrdudes/avr-libc/issues/931`) to set up FLMAP according to symbol `__flmap`.

`-nodevicespecs`

Don't add `-specs=device-specs/specs-`*`mcu`* to the compiler driver's command line. The user takes responsibility for supplying the sub-processes like compiler proper, assembler and linker with appropriate command line options. This means that the user has to supply her private device specs file by means of `-specs=`*`path-to-specs-file`*. There is no more need for option `-mmcu=`*`mcu`*.

This option can also serve as a replacement for the older way of specifying custom device-specs files that needed `-B` *`some-path`* to point to a directory which contains a folder named `device-specs` which contains a specs file named `specs-`*`mcu`*, where *mcu* was specified by `-mmcu=`*`mcu`*.

`-Waddr-space-convert`

Warn about conversions between address spaces in the case where the resulting address space is not contained in the incoming address space.

`-Wmisspelled-isr`

Warn if the ISR is misspelled, i.e. without __vector prefix. Enabled by default.

3.20.6.1 AVR Optimization Options

The following options are pure optimization options. Options `-mgas-isr-prologues`, `-mmain-is-OS_task`, `-mno-call-main` and `-mrelax` from above are only *almost* optimization options, since there are rare occasions where their different code generation matters.

`-maccumulate-args`
: Accumulate outgoing function arguments and acquire/release the needed stack space for outgoing function arguments once in function prologue/epilogue. Without this option, outgoing arguments are pushed before calling a function and popped afterwards. See also the `-fdefer-pop` Section 3.12 [optimization option], page 194.

  Popping the arguments after the function call can be expensive on AVR so that accumulating the stack space might lead to smaller executables because arguments need not be removed from the stack after such a function call.

  This option can lead to reduced code size for functions that perform several calls to functions that get their arguments on the stack like calls to printf-like functions.

`-mbranch-cost=`*`cost`*
: Set the branch costs for conditional branch instructions to *cost*. Reasonable values for *cost* are small, non-negative integers. The default branch cost is 0.

`-mcall-prologues`
: Functions prologues/epilogues are expanded as calls to appropriate subroutines. Code size is smaller.

`-mfuse-add`
`-mno-fuse-add`
`-mfuse-add=`*`level`*
: Optimize indirect memory accesses on reduced Tiny devices. The default uses `level=1` for optimizations `-Og` and `-O1`, and `level=2` for higher optimizations. Valid values for *level* are `0`, `1` and `2`.

`-mfuse-move`
`-mno-fuse-move`
`-mfuse-move=`*`level`*
: Run a post reload optimization pass that tries to fuse move instructions and to split multi-byte instructions into 8-bit operations. The default uses `level=3` for optimization `-O1`, and `level=23` for higher optimizations. Valid values for *level* are in the range `0` . . . `23` which is a 3:2:2:2 mixed radix value. Each digit controls some aspect of the optimization.

`-mfuse-move2`
: Run a post combine optimization pass that tries to fuse move instructions.

`-mstrict-X`
: Use address register `X` in a way proposed by the hardware. This means that `X` is only used in indirect, post-increment or pre-decrement addressing.

  Without this option, the `X` register may be used in the same way as `Y` or `Z` which then is emulated by additional instructions. For example, loading a value with

X+const addressing with a small non-negative const < 64 to a register *Rn* is performed as

```
adiw r26, const   ; X += const
ld   Rn, X        ; Rn = *X
sbiw r26, const   ; X -= const
```

`-msplit-bit-shift`
: Split multi-byte shifts with a constant offset into a shift with a byte offset and a residual shift with a non-byte offset. This optimization is turned on per default for `-O2` and higher, including `-Os` but excluding `-Oz`. Splitting of shifts with a constant offset that is a multiple of 8 is controlled by `-mfuse-move`.

`-msplit-ldst`
: Split multi-byte loads and stores into several byte loads and stores. This optimization is turned on per default for `-O2` and higher.

`-muse-nonzero-bits`
: Enable optimizations that are only possible when some bits in a register are always zero. This optimization is turned on per default for `-O2` and higher.

3.20.6.2 EIND and Devices with More Than 128 Ki Bytes of Flash

Pointers in the implementation are 16 bits wide. The address of a function or label is represented as word address so that indirect jumps and calls can target any code address in the range of 64 Ki words.

In order to facilitate indirect jump on devices with more than 128 Ki bytes of program memory space, there is a special function register called `EIND` that serves as most significant part of the target address when `EICALL` or `EIJMP` instructions are used.

Indirect jumps and calls on these devices are handled as follows by the compiler and are subject to some limitations:

- The compiler never sets `EIND`.
- The compiler uses `EIND` implicitly in `EICALL`/`EIJMP` instructions or might read `EIND` directly in order to emulate an indirect call/jump by means of a `RET` instruction.
- The compiler assumes that `EIND` never changes during the startup code or during the application. In particular, `EIND` is not saved/restored in function or interrupt service routine prologue/epilogue.
- For indirect calls to functions and computed goto, the linker generates *stubs*. Stubs are jump pads sometimes also called *trampolines*. Thus, the indirect call/jump jumps to such a stub. The stub contains a direct jump to the desired address.
- Linker relaxation must be turned on so that the linker generates the stubs correctly in all situations. See the compiler option `-mrelax` and the linker option `--relax`. There are corner cases where the linker is supposed to generate stubs but aborts without relaxation and without a helpful error message.
- The default linker script is arranged for code with `EIND = 0`. If code is supposed to work for a setup with `EIND != 0`, a custom linker script has to be used in order to place the sections whose name start with `.trampolines` into the segment where `EIND` points to.

- The startup code from libgcc never sets `EIND`. Notice that startup code is a blend of code from libgcc and AVR-LibC. For the impact of AVR-LibC on `EIND`, see the AVR-LibC user manual (`https://avrdudes.github.io/avr-libc/avr-libc-user-manual/`).
- It is legitimate for user-specific startup code to set up `EIND` early, for example by means of initialization code located in section `.init3`. Such code runs prior to general startup code that initializes RAM and calls constructors, but after the bit of startup code from AVR-LibC that sets `EIND` to the segment where the vector table is located.

```
#include <avr/io.h>

static void
__attribute__((section(".init3"),naked,used,no_instrument_function))
init3_set_eind (void)
{
  __asm volatile ("ldi r24,pm_hh8(__trampolines_start)\n\t"
                  "out %i0,r24" :: "n" (&EIND) : "r24","memory");
}
```

  The `__trampolines_start` symbol is defined in the linker script.
- Stubs are generated automatically by the linker if the following two conditions are met:
  - The address of a label is taken by means of the `gs` modifier (short for *generate stubs*) like so:

    ```
    LDI r24, lo8(gs(func))
    LDI r25, hi8(gs(func))
    ```

  - The final location of that label is in a code segment *outside* the segment where the stubs are located.
- The compiler emits such `gs` modifiers for code labels in the following situations:
  - Taking address of a function or code label.
  - Computed goto.
  - If prologue-save function is used, see `-mcall-prologues` command-line option.
  - Switch/case dispatch tables. If you do not want such dispatch tables you can specify the `-fno-jump-tables` command-line option.
  - C and C++ constructors/destructors called during startup/shutdown.
  - If the tools hit a `gs()` modifier explained above.
- Jumping to non-symbolic addresses like so is *not* supported:

```
int main (void)
{
    /* Call function at word address 0x2 */
    return ((int(*)(void)) 0x2)();
}
```

  Instead, a stub has to be set up, i.e. the function has to be called through a symbol (`func_4` in the example):

```
int main (void)
{
    extern int func_4 (void);
```

```
        /* Call function at byte address 0x4 */
        return func_4();
    }
```

and the application be linked with `-Wl,--defsym,func_4=0x4`. Alternatively, `func_4` can be defined in the linker script.

3.20.6.3 Handling of the RAMPD, RAMPX, RAMPY and RAMPZ Special Function Registers

Some AVR devices support memories larger than the 64 KiB range that can be accessed with 16-bit pointers. To access memory locations outside this 64 KiB range, the content of a `RAMP` register is used as high part of the address: The `X`, `Y`, `Z` address register is concatenated with the `RAMPX`, `RAMPY`, `RAMPZ` special function register, respectively, to get a wide address. Similarly, `RAMPD` is used together with direct addressing.

- The startup code initializes the `RAMP` special function registers with zero.
- If a [AVR Named Address Spaces], page 617, other than generic or `__flash` is used, then `RAMPZ` is set as needed before the operation.
- If the device supports RAM larger than 64 KiB and the compiler needs to change `RAMPZ` to accomplish an operation, `RAMPZ` is reset to zero after the operation.
- If the device comes with a specific `RAMP` register, the ISR prologue/epilogue saves/restores that SFR and initializes it with zero in case the ISR code might (implicitly) use it.
- RAM larger than 64 KiB is not supported by GCC for AVR targets. If you use inline assembler to read from locations outside the 16-bit address range and change one of the `RAMP` registers, you must reset it to zero after the access.

3.20.6.4 AVR Built-in Macros

GCC defines several built-in macros so that the user code can test for the presence or absence of features. Almost any of the following built-in macros are deduced from device capabilities and thus triggered by the `-mmcu=` command-line option.

For even more AVR-specific built-in macros see [AVR Named Address Spaces], page 617, and Section 7.13.8 [AVR Built-in Functions], page 883.

`__AVR_ARCH__`
: Build-in macro that resolves to a decimal number that identifies the architecture and depends on the `-mmcu=`*mcu* option. Possible values are:

  `2`, `25`, `3`, `31`, `35`, `4`, `5`, `51`, `6`

  for *mcu*=`avr2`, `avr25`, `avr3`, `avr31`, `avr35`, `avr4`, `avr5`, `avr51`, `avr6`,

  respectively and

  `100`, `102`, `103`, `104`, `105`, `106`, `107`

  for *mcu*=`avrtiny`, `avrxmega2`, `avrxmega3`, `avrxmega4`, `avrxmega5`, `avrxmega6`, `avrxmega7`, respectively. If *mcu* specifies a device, this built-in macro is set accordingly. For example, with `-mmcu=atmega8` the macro is defined to `4`.

`__AVR_Device__`
: Setting `-mmcu=device` defines this built-in macro which reflects the device's name. For example, `-mmcu=atmega8` defines the built-in macro `__AVR_ATmega8__`, `-mmcu=attiny261a` defines `__AVR_ATtiny261A__`, etc.

  The built-in macros' names follow the scheme `__AVR_Device__` where *Device* is the device name as from the AVR user manual. The difference between *Device* in the built-in macro and *device* in `-mmcu=device` is that the latter is always lowercase.

  If *device* is not a device but only a core architecture like '`avr51`', this macro is not defined.

`__AVR_DEVICE_NAME__`
: Setting `-mmcu=device` defines this built-in macro to the device's name. For example, with `-mmcu=atmega8` the macro is defined to `atmega8`.

  If *device* is not a device but only a core architecture like '`avr51`', this macro is not defined.

`__AVR_CVT__`
: The code is being compiled with option `-mcvt` to use a *compact vector table*.

`__AVR_XMEGA__`
: The device / architecture belongs to the XMEGA family of devices.

`__AVR_HAVE_ADIW__`
: The device has the `ADIW` and `SBIW` instructions.

`__AVR_HAVE_ELPM__`
: The device has the `ELPM` instruction.

`__AVR_HAVE_ELPMX__`
: The device has the `ELPM Rn,Z` and `ELPM Rn,Z+` instructions.

`__AVR_HAVE_LPMX__`
: The device has the `LPM Rn,Z` and `LPM Rn,Z+` instructions.

`__AVR_HAVE_MOVW__`
: The device has the `MOVW` instruction to perform 16-bit register-register moves.

`__AVR_HAVE_MUL__`
: The device has a hardware multiplier.

`__AVR_HAVE_JMP_CALL__`
: The device has the `JMP` and `CALL` instructions. This is the case for devices with more than 8 KiB of program memory.

`__AVR_HAVE_EIJMP_EICALL__`
`__AVR_3_BYTE_PC__`
: The device has the `EIJMP` and `EICALL` instructions. This is the case for devices with more than 128 KiB of program memory. This also means that the program counter (PC) is 3 bytes wide.

`__AVR_2_BYTE_PC__`
: The program counter (PC) is 2 bytes wide. This is the case for devices with up to 128 KiB of program memory.

`__AVR_HAVE_8BIT_SP__`
`__AVR_HAVE_16BIT_SP__`
The stack pointer (SP) register is treated as 8-bit respectively 16-bit register by the compiler. The definition of these macros is affected by `-mtiny-stack`.

`__AVR_HAVE_SPH__`
`__AVR_SP8__`
The device has the SPH (high part of stack pointer) special function register or has an 8-bit stack pointer, respectively. The definition of these macros is affected by `-mmcu=` and in the cases of `-mmcu=avr2` and `-mmcu=avr25` also by `-msp8`.

`__AVR_HAVE_RAMPD__`
`__AVR_HAVE_RAMPX__`
`__AVR_HAVE_RAMPY__`
`__AVR_HAVE_RAMPZ__`
The device has the `RAMPD`, `RAMPX`, `RAMPY`, `RAMPZ` special function register, respectively.

`__NO_INTERRUPTS__`
This macro reflects the `-mno-interrupts` command-line option.

`__AVR_ERRATA_SKIP__`
`__AVR_ERRATA_SKIP_JMP_CALL__`
Some AVR devices (AT90S8515, ATmega103) must not skip 32-bit instructions because of a hardware erratum. Skip instructions are `SBRS`, `SBRC`, `SBIS`, `SBIC` and `CPSE`. The second macro is only defined if `__AVR_HAVE_JMP_CALL__` is also set.

`__AVR_ISA_RMW__`
The device has Read-Modify-Write instructions (XCH, LAC, LAS and LAT).

`__AVR_SFR_OFFSET__=`*`offset`*
Instructions that can address I/O special function registers directly like `IN`, `OUT`, `SBI`, etc. may use a different address as if addressed by an instruction to access RAM like `LD` or `STS`. This offset depends on the device architecture and has to be subtracted from the RAM address in order to get the respective I/O address.

`__AVR_SHORT_CALLS__`
The `-mshort-calls` command line option is set.

`__AVR_PM_BASE_ADDRESS__=`*`addr`*
Some devices support reading from flash memory by means of `LD*` instructions. The flash memory is seen in the data address space at an offset of `__AVR_PM_BASE_ADDRESS__`. If this macro is not defined, this feature is not available. If defined, the address space is linear and there is no need to put `.rodata` into RAM. This is handled by the default linker description file, and is currently available for `avrtiny` and `avrxmega3`. Even more convenient, there is no need to use address spaces like `__flash` or features like attribute `progmem` and `pgm_read_*`.

`__AVR_HAVE_FLMAP__`
This macro is defined provided the following conditions are met:

- The device has the `NVMCTRL_CTRLB.FLMAP` bitfield. This applies to the AVR64* and AVR128* devices.
- It's not known at assembler-time which emulation will be used.

This implies the compiler was configured with GNU Binutils that implement PR31124 (`https://sourceware.org/PR31124`).

`__AVR_RODATA_IN_RAM__`
This macro is undefined when the code is compiled for a core architecture.

When the code is compiled for a device, the macro is defined to 1 when the `.rodata` sections for read-only data is located in RAM; and defined to 0, otherwise.

`__WITH_AVRLIBC__`
The compiler is configured to be used together with AVR-LibC. See the `--with-avrlibc` configure option.

`__HAVE_SIGNAL_N__`
The compiler supports the `signal(`*num*`)` and `interrupt(`*num*`)` Section 6.4.1.6 [function attributes], page 659, with an argument *num* that specifies the number of the interrupt service routine.

`__HAVE_DOUBLE_MULTILIB__`
Defined if `-mdouble=` acts as a multilib option.

`__HAVE_DOUBLE32__`
`__HAVE_DOUBLE64__`
Defined if the compiler supports 32-bit double resp. 64-bit double. The actual layout is specified by option `-mdouble=`.

`__DEFAULT_DOUBLE__`
The size in bits of `double` if `-mdouble=` is not set. To test the layout of `double` in a program, use the built-in macro `__SIZEOF_DOUBLE__`.

`__HAVE_LONG_DOUBLE32__`
`__HAVE_LONG_DOUBLE64__`
`__HAVE_LONG_DOUBLE_MULTILIB__`
`__DEFAULT_LONG_DOUBLE__`
Same as above, but for `long double` instead of `double`.

`__WITH_DOUBLE_COMPARISON__`
Reflects the `--with-double-comparison={tristate|bool|libf7}` configure option (`https://gcc.gnu.org/install/configure.html#avr`) and is defined to `2` or `3`.

`__WITH_LIBF7_LIBGCC__`
`__WITH_LIBF7_MATH__`
`__WITH_LIBF7_MATH_SYMBOLS__`
Reflects the `--with-libf7={libgcc|math|math-symbols}` configure option (`https://gcc.gnu.org/install/configure.html#avr`).

3.20.6.5 AVR Internal Options

The following options are used internally by the compiler and to communicate between device specs files and the compiler proper. You don't need to set these options by hand, in particular they are not optimization options. Using these options in the wrong way may lead to sub-optimal or wrong code. They are documented for completeness, and in order to get a better understanding of device specs (`https://gcc.gnu.org/wiki/avr-gcc#spec-files`) files.

`-mn-flash=`*num*
: Assume that the flash memory has a size of *num* times 64 KiB. This determines which `__flash`*N* address spaces are available.

`-mflmap`
: The device has the `FLMAP` bit field located in special function register `NVMCTRL_CTRLB`.

`-mrmw`
: Assume that the device supports the Read-Modify-Write instructions `XCH`, `LAC`, `LAS` and `LAT`.

`-mshort-calls`
: Assume that `RJMP` and `RCALL` can target the whole program memory. This option is used for multilib generation and selection for the devices from architecture `avrxmega3`.

`-mskip-bug`
: Generate code without skips (`CPSE`, `SBRS`, `SBRC`, `SBIS`, `SBIC`) over 32-bit instructions.

`-msp8`
: Treat the stack pointer register as an 8-bit register, i.e. assume the high byte of the stack pointer is zero. This option is used by the compiler to select and build multilibs for architectures `avr2` and `avr25`. These architectures mix devices with and without `SPH`.

3.20.7 Blackfin Options

`-mcpu=`*cpu*[`-`*sirevision*]
: Specifies the name of the target Blackfin processor. Currently, *cpu* can be one of '`bf512`', '`bf514`', '`bf516`', '`bf518`', '`bf522`', '`bf523`', '`bf524`', '`bf525`', '`bf526`', '`bf527`', '`bf531`', '`bf532`', '`bf533`', '`bf534`', '`bf536`', '`bf537`', '`bf538`', '`bf539`', '`bf542`', '`bf544`', '`bf547`', '`bf548`', '`bf549`', '`bf542m`', '`bf544m`', '`bf547m`', '`bf548m`', '`bf549m`', '`bf561`', '`bf592`'.

: The optional *sirevision* specifies the silicon revision of the target Blackfin processor. Any workarounds available for the targeted silicon revision are enabled. If *sirevision* is '`none`', no workarounds are enabled. If *sirevision* is '`any`', all workarounds for the targeted processor are enabled. The `__SILICON_REVISION__` macro is defined to two hexadecimal digits representing the major and minor numbers in the silicon revision. If *sirevision* is '`none`', the `__SILICON_REVISION__` is not defined. If *sirevision* is '`any`', the `__SILICON_REVISION__` is defined to be `0xffff`. If this optional *sirevision* is not used, GCC assumes the latest known silicon revision of the targeted Blackfin processor.

GCC defines a preprocessor macro for the specified *cpu*. For the 'bfin-elf' toolchain, this option causes the hardware BSP provided by libgloss to be linked in if -msim is not given.

Without this option, 'bf532' is used as the processor by default.

Note that support for 'bf561' is incomplete. For 'bf561', only the preprocessor macro is defined.

-msim
: Specifies that the program will be run on the simulator. This causes the simulator BSP provided by libgloss to be linked in. This option has effect only for 'bfin-elf' toolchain. Certain other options, such as -mid-shared-library and -mfdpic, imply -msim.

-momit-leaf-frame-pointer
: Don't keep the frame pointer in a register for leaf functions. This avoids the instructions to save, set up and restore frame pointers and makes an extra register available in leaf functions.

-mspecld-anomaly
-mno-specld-anomaly
: When enabled, the compiler ensures that the generated code does not contain speculative loads after jump instructions. If this option is used, __WORKAROUND_SPECULATIVE_LOADS is defined.

-mcsync-anomaly
-mno-csync-anomaly
: When enabled, the compiler ensures that the generated code does not contain CSYNC or SSYNC instructions too soon after conditional branches. If this option is used, __WORKAROUND_SPECULATIVE_SYNCS is defined.

-mlow64k
-mno-low64k
: When enabled, the compiler is free to take advantage of the knowledge that the entire program fits into the low 64k of memory. The default behavior is to assume that the program is arbitrarily large (-mno-low64k).

-mstack-check-l1
: Do stack checking using information placed into L1 scratchpad memory by the uClinux kernel.

-mid-shared-library
-mno-id-shared-library
: Generate code that supports shared libraries via the library ID method. This allows for execute in place and shared libraries in an environment without virtual memory management. This option implies -fPIC. With a 'bfin-elf' target, this option implies -msim. The default is -mno-id-shared-library, to generate code that doesn't assume ID-based shared libraries are being used.

-mleaf-id-shared-library
-mno-leaf-id-shared-library
: Generate code that supports shared libraries via the library ID method, but assumes that this library or executable won't link against any other ID shared libraries. That allows the compiler to use faster code for jumps and calls.

The default is `-mno-leaf-id-shared-library`, in which the no assumption is made that the code being compiled won't link against any ID shared libraries. Slower code is generated for jump and call insns.

`-mshared-library-id=n`
: Specifies the identification number of the ID-based shared library being compiled. Specifying a value of 0 generates more compact code; specifying other values forces the allocation of that number to the current library but is no more space- or time-efficient than omitting this option.

`-msep-data`
`-mno-sep-data`
: Generate code that allows the data segment to be located in a different area of memory from the text segment. This allows for execute in place in an environment without virtual memory management by eliminating relocations against the text section. The default is `-mno-sep-data`, which tells GCC to generate code that assumes that the data segment follows the text segment.

`-mlong-calls`
`-mno-long-calls`
: Tells the compiler to perform function calls by first loading the address of the function into a register and then performing a subroutine call on this register. This switch is needed if the target function lies outside of the 24-bit addressing range of the offset-based version of subroutine call instruction.

This feature is not enabled by default. Specifying `-mno-long-calls` restores the default behavior. Note these switches have no effect on how the compiler generates code to handle function calls via function pointers.

`-mfast-fp`
: Link with the fast floating-point library. This library relaxes some of the IEEE floating-point standard's rules for checking inputs against Not-a-Number (NAN), in the interest of performance.

`-minline-plt`
: Enable inlining of PLT entries in function calls to functions that are not known to bind locally. It has no effect without `-mfdpic`.

`-mmulticore`
: Build a standalone application for multicore Blackfin processors. This option causes proper start files and link scripts supporting multicore to be used, and defines the macro `__BFIN_MULTICORE`. It can only be used with `-mcpu=bf561`[`-`*`sirevision`*].

This option can be used with `-mcorea` or `-mcoreb`, which selects the one-application-per-core programming model. Without `-mcorea` or `-mcoreb`, the single-application/dual-core programming model is used. In this model, the main function of Core B should be named as `coreb_main`.

If this option is not used, the single-core application programming model is used.

`-mcorea`
: Build a standalone application for Core A of BF561 when using the one-application-per-core programming model. Proper start files and link scripts

are used to support Core A, and the macro `__BFIN_COREA` is defined. This option can only be used in conjunction with `-mmulticore`.

`-mcoreb` Build a standalone application for Core B of BF561 when using the one-application-per-core programming model. Proper start files and link scripts are used to support Core B, and the macro `__BFIN_COREB` is defined. When this option is used, `coreb_main` should be used instead of `main`. This option can only be used in conjunction with `-mmulticore`.

`-msdram` Build a standalone application for SDRAM. Proper start files and link scripts are used to put the application into SDRAM, and the macro `__BFIN_SDRAM` is defined. The loader should initialize SDRAM before loading the application.

`-micplb` Assume that ICPLBs are enabled at run time. This has an effect on certain anomaly workarounds. For Linux targets, the default is to assume ICPLBs are enabled; for standalone applications the default is off.

3.20.8 C6X Options

`-march=name`
This specifies the name of the target architecture. GCC uses this name to determine what kind of instructions it can emit when generating assembly code. Permissible names are: '`c62x`', '`c64x`', '`c64x+`', '`c67x`', '`c67x+`', '`c674x`'.

`-mbig-endian`
Generate code for a big-endian target.

`-mlittle-endian`
Generate code for a little-endian target. This is the default.

`-msim` Choose startup files and linker script suitable for the simulator.

`-msdata=default`
Put small global and static data in the `.neardata` section, which is pointed to by register `B14`. Put small uninitialized global and static data in the `.bss` section, which is adjacent to the `.neardata` section. Put small read-only data into the `.rodata` section. The corresponding sections used for large pieces of data are `.fardata`, `.far` and `.const`.

`-msdata=all`
Put all data, not just small objects, into the sections reserved for small data, and use addressing relative to the `B14` register to access them.

`-msdata=none`
Make no use of the sections reserved for small data, and use absolute addresses to access all data. Put all initialized global and static data in the `.fardata` section, and all uninitialized data in the `.far` section. Put all constant data into the `.const` section.

`-mdsbt` Compile for the DSBT shared library ABI. This option is required to compile with `-fpic` or `-fPIC`, and implies `-fpic`.

`-mlong-calls`
Avoid generating PC-relative calls; use indirection instead.

3.20.9 CRIS Options

These options are defined specifically for the CRIS ports.

`-march=architecture-type`
`-mcpu=architecture-type`

Generate code for the specified architecture. The choices for *architecture-type* are 'v3', 'v8' and 'v10' for respectively ETRAX 4, ETRAX 100, and ETRAX 100 LX. Default is 'v0'.

`-mtune=architecture-type`

Tune to *architecture-type* everything applicable about the generated code, except for the ABI and the set of available instructions. The choices for *architecture-type* are the same as for `-march=architecture-type`.

`-mmax-stack-frame=n`

Warn when the stack frame of a function exceeds *n* bytes.

`-metrax4`
`-metrax100`

The options `-metrax4` and `-metrax100` are synonyms for `-march=v3` and `-march=v8` respectively.

`-mmul-bug-workaround`
`-mno-mul-bug-workaround`

Work around a bug in the `muls` and `mulu` instructions for CPU models where it applies. This option is disabled by default.

`-mpdebug` Enable CRIS-specific verbose debug-related information in the assembly code. This option also has the effect of turning off the '#NO_APP' formatted-code indicator to the assembler at the beginning of the assembly file.

`-mcc-init`

Do not use condition-code results from previous instruction; always emit compare and test instructions before use of condition codes.

`-mno-side-effects`

Do not emit instructions with side effects in addressing modes other than post-increment.

`-mstack-align`
`-mno-stack-align`
`-mdata-align`
`-mno-data-align`
`-mconst-align`
`-mno-const-align`

These options ('no-' options) arrange (eliminate arrangements) for the stack frame, individual data and constants to be aligned for the maximum single data access size for the chosen CPU model. The default is to arrange for 32-bit alignment. ABI details such as structure layout are not affected by these options.

`-m32-bit`
`-m16-bit`
`-m8-bit` Similar to the stack- data- and const-align options above, these options arrange for stack frame, writable data and constants to all be 32-bit, 16-bit or 8-bit aligned. The default is 32-bit alignment.

`-mno-prologue-epilogue`
`-mprologue-epilogue`
With `-mno-prologue-epilogue`, the normal function prologue and epilogue which set up the stack frame are omitted and no return instructions or return sequences are generated in the code. Use this option only together with visual inspection of the compiled code: no warnings or errors are generated when call-saved registers must be saved, or storage for local variables needs to be allocated.

`-mbest-lib-options`
`-moverride-best-lib-options`
`-mbest-lib-options` selects the most feature-enabling options allowed by other options. This option has no '`no-`' form, but `-moverride-best-lib-options` disables it regardless of the relative order of the two options on the command line.

`-mtrap-using-break8`
Emit traps as '`break 8`'. This is the default for CRIS v3 and up. If disabled, calls to `abort` are used instead.

`-mtrap-unaligned-atomic`
Emit checks causing '`break 8`' instructions to execute when applying atomic builtins on misaligned memory.

`-munaligned-atomic-may-use-library`
Handle atomic builtins that may be applied to unaligned data by calling library functions. This option overrides `-mtrap-unaligned-atomic`.

`-sim` This option arranges to link with input-output functions from a simulator library. Code, initialized data and zero-initialized data are allocated consecutively.

`-sim2` Like `-sim`, but pass linker options to locate initialized data at 0x40000000 and zero-initialized data at 0x80000000.

3.20.10 C-SKY Options

GCC supports these options when compiling for C-SKY V2 processors.

`-march=`*`arch`*
Specify the C-SKY target architecture. Valid values for *arch* are: '`ck801`', '`ck802`', '`ck803`', '`ck807`', and '`ck810`'. The default is '`ck810`'.

`-mcpu=`*`cpu`*
Specify the C-SKY target processor. Valid values for *cpu* are: '`ck801`', '`ck801t`', '`ck802`', '`ck802t`', '`ck802j`', '`ck803`', '`ck803h`', '`ck803t`', '`ck803ht`', '`ck803f`', '`ck803fh`', '`ck803e`', '`ck803eh`', '`ck803et`', '`ck803eht`', '`ck803ef`',

'ck803efh', 'ck803ft', 'ck803eft', 'ck803efht', 'ck803r1', 'ck803hr1', 'ck803tr1', 'ck803htr1', 'ck803fr1', 'ck803fhr1', 'ck803er1', 'ck803ehr1', 'ck803etr1', 'ck803ehtr1', 'ck803efr1', 'ck803efhr1', 'ck803ftr1', 'ck803eftr1', 'ck803efhtr1', 'ck803s', 'ck803st', 'ck803se', 'ck803sf', 'ck803sef', 'ck803seft', 'ck807e', 'ck807ef', 'ck807', 'ck807f', 'ck810e', 'ck810et', 'ck810ef', 'ck810eft', 'ck810', 'ck810v', 'ck810f', 'ck810t', 'ck810fv', 'ck810tv', 'ck810ft', and 'ck810ftv'.

`-mbig-endian`
`-mlittle-endian`
Select big- or little-endian code. The default is little-endian.

`-mfloat-abi=`*name*
Specifies which floating-point ABI to use. Permissible values are: 'soft', 'softfp' and 'hard'.

Specifying 'soft' causes GCC to generate output containing library calls for floating-point operations. 'softfp' allows the generation of code using hardware floating-point instructions, but still uses the soft-float calling conventions. 'hard' allows generation of floating-point instructions and uses FPU-specific calling conventions.

The default depends on the specific target configuration. Note that the hard-float and soft-float ABIs are not link-compatible; you must compile your entire program with the same ABI, and link with a compatible set of libraries.

`-mdouble-float`
`-mno-double-float`
When `-mhard-float` is in effect, enable generation of double-precision float instructions. This is the default except when compiling for CK803.

`-mfdivdu`
`-mno-fdivdu`
When `-mhard-float` is in effect, enable generation of `frecipd`, `fsqrtd`, and `fdivd` instructions. This is the default except when compiling for CK803.

`-mfpu=`*fpu*
Select the floating-point processor. This option can only be used with `-mhard-float`. Values for *fpu* are 'fpv2_sf' (equivalent to '-mno-double-float -mno-fdivdu'), 'fpv2' ('-mdouble-float -mno-divdu'), and 'fpv2_divd' ('-mdouble-float -mdivdu').

`-melrw`
`-mno-elrw`
Enable the extended `lrw` instruction. This option defaults to on for CK801 and off otherwise.

`-mistack`
`-mno-istack`
Enable interrupt stack instructions; the default is off.

The `-mistack` option is required to handle the `interrupt` and `isr` function attributes (see Section 6.4.1.9 [C-SKY Function Attributes], page 663).

`-mmp`
`-mno-mp` Enable multiprocessor instructions; the default is off.

`-mcp`
`-mno-cp` Enable coprocessor instructions; the default is off.

`-mcache`
`-mno-cache`
: Enable coprocessor instructions; the default is off.

`-msecurity`
`-mno-security`
: Enable C-SKY security instructions; the default is off.

`-mtrust`
`-mno-trust`
: Enable C-SKY trust instructions; the default is off.

`-mdsp`
`-mno-dsp`
`-medsp`
`-mno-edsp`
`-mvdsp`
`-mno-vdsp`
: Enable C-SKY DSP, Enhanced DSP, or Vector DSP instructions, respectively. All of these options default to off.

`-mdiv`
`-mno-div` Generate divide instructions. Default is off.

`-msmart`
`-mno-smart`
: Generate code for Smart Mode, using only registers numbered 0-7 to allow use of 16-bit instructions. This option is ignored for CK801 where this is the required behavior, and it defaults to on for CK802. For other targets, the default is off.

`-mhigh-registers`
`-mno-high-registers`
: Generate code using the high registers numbered 16-31. This option is not supported on CK801, CK802, or CK803, and is enabled by default for other processors.

`-manchor`
`-mno-anchor`
: Generate code using global anchor symbol addresses.

`-mpushpop`
`-mno-pushpop`
: Generate code using `push` and `pop` instructions. This option defaults to on.

`-mmultiple-stld`
`-mno-multiple-stld`
: Generate code using `stm` and `ldm` instructions. This option isn't supported on CK801 but is enabled by default on other processors.

`-mconstpool`
`-mno-constpool`
Create constant pools in the compiler instead of deferring it to the assembler. This option is the default and required for correct code generation on CK801 and CK802, and is optional on other processors.

`-mstack-size`
`-mno-stack-size`
Emit `.stack_size` directives for each function in the assembly output. This option defaults to off.

`-mccrt`
`-mno-ccrt`
Generate code for the C-SKY compiler runtime instead of libgcc. This option defaults to off.

`-mbranch-cost=`*n*
Set the branch costs to roughly `n` instructions. The default is 1.

`-msched-prolog`
`-mno-sched-prolog`
Permit scheduling of function prologue and epilogue sequences. Using this option can result in code that is not compliant with the C-SKY V2 ABI prologue requirements and that cannot be debugged or backtraced. It is disabled by default.

`-msim`
`-mno-sim` Links the library libsemi.a which is in compatible with simulator. Applicable to ELF compiler only.

3.20.11 Cygwin and MinGW Options

These additional options are available for Microsoft Windows targets:

`-mconsole`
This option specifies that a console application is to be generated, by instructing the linker to set the PE header subsystem type required for console applications. This option is available for Cygwin and MinGW targets and is enabled by default on those targets.

`-mcrtdll=`*library*
Preprocess, compile or link with specified C RunTime DLL *library*. This option adjust predefined macros `__CRTDLL__`, `__MSVCRT__`, `_UCRT` and `__MSVCRT_VERSION__` for specified CRT *library*, choose start file for CRT *library* and link with CRT *library*. Recognized CRT library names for proprocessor are: `crtdll*`, `msvcrt10*`, `msvcrt20*`, `msvcrt40*`, `msvcr40*`, `msvcrtd*`, `msvcrt-os*`, `msvcr70*`, `msvcr71*`, `msvcr80*`, `msvcr90*`, `msvcr100*`, `msvcr110*`, `msvcr120*` and `ucrt*`. If this options is not specified then the default MinGW import library `msvcrt` is used for linking and no other adjustment for preprocessor is done. MinGW import library `msvcrt` is just a symlink to (or a copy of) another MinGW CRT import library chosen during MinGW compilation. MinGW import library `msvcrt-os` is

for Windows system CRT DLL library `msvcrt.dll` and in most cases is the default MinGW import library. Generally speaking, changing the CRT DLL requires recompiling the entire MinGW CRT. This option is for experimental and testing purposes only. This option is available for MinGW targets.

`-mdll` This option is available for Cygwin and MinGW targets. It specifies that a DLL—a dynamic link library—is to be generated, enabling the selection of the required runtime startup object and entry point.

`-mnop-fun-dllimport`
: This option is available for Cygwin and MinGW targets. It specifies that the `dllimport` attribute should be ignored.

`-mthreads`
: This option is available for MinGW targets. It specifies that MinGW-specific thread support is to be used.

`-municode`
: This option is available for MinGW-w64 targets. It causes the `UNICODE` preprocessor macro to be predefined, and chooses Unicode-capable runtime startup code.

`-mwin32` This option is available for Cygwin and MinGW targets. It specifies that the typical Microsoft Windows predefined macros are to be set in the pre-processor, but does not influence the choice of runtime library/startup code.

`-mwindows`
: This option is available for Cygwin and MinGW targets. It specifies that a GUI application is to be generated by instructing the linker to set the PE header subsystem type appropriately.

`-fno-set-stack-executable`
: This option is available for MinGW targets. It specifies that the executable flag for the stack used by nested functions isn't set. This is necessary for binaries running in kernel mode of Microsoft Windows, as there the User32 API, which is used to set executable privileges, isn't available.

`-fwritable-relocated-rdata`
: This option is available for MinGW and Cygwin targets. It specifies that relocated-data in read-only section is put into the `.data` section. This is a necessary for older runtimes not supporting modification of `.rdata` sections for pseudo-relocation.

`-mpe-aligned-commons`
: This option is available for Cygwin and MinGW targets. It specifies that the GNU extension to the PE file format that permits the correct alignment of COMMON variables should be used when generating code. It is enabled by default if GCC detects that the target assembler found during configuration supports the feature.

See also under Section 3.20.54 [x86 Options], page 534, for standard options.

3.20.12 Darwin Options

These options are defined for all architectures running the Darwin operating system.

FSF GCC on Darwin does not create "fat" object files; it creates an object file for the single architecture that GCC was built to target. Apple's GCC on Darwin does create "fat" files if multiple `-arch` options are used; it does so by running the compiler or linker multiple times and joining the results together with `lipo`.

The subtype of the file created (like 'ppc7400' or 'ppc970' or 'i686') is determined by the flags that specify the ISA that GCC is targeting, like `-mcpu` or `-march`. The `-force_cpusubtype_ALL` option can be used to override this.

The Darwin tools vary in their behavior when presented with an ISA mismatch. The assembler, `as`, only permits instructions to be used that are valid for the subtype of the file it is generating, so you cannot put 64-bit instructions in a 'ppc750' object file. The linker for shared libraries, `/usr/bin/libtool`, fails and prints an error if asked to create a shared library with a less restrictive subtype than its input files (for instance, trying to put a 'ppc970' object file in a 'ppc7400' library). The linker for executables, `ld`, quietly gives the executable the most restrictive subtype of any of its input files.

`-F`*dir*
: Add the framework directory *dir* to the head of the list of directories to be searched for header files. These directories are interleaved with those specified by `-I` options and are scanned in a left-to-right order.

  A framework directory is a directory with frameworks in it. A framework is a directory with a `Headers` and/or `PrivateHeaders` directory contained directly in it that ends in `.framework`. The name of a framework is the name of this directory excluding the `.framework`. Headers associated with the framework are found in one of those two directories, with `Headers` being searched first. A subframework is a framework directory that is in a framework's `Frameworks` directory. Includes of subframework headers can only appear in a header of a framework that contains the subframework, or in a sibling subframework header. Two subframeworks are siblings if they occur in the same framework. A subframework should not have the same name as a framework; a warning is issued if this is violated. Currently a subframework cannot have subframeworks; in the future, the mechanism may be extended to support this. The standard frameworks can be found in `/System/Library/Frameworks` and `/Library/Frameworks`. An example include looks like `#include <Framework/header.h>`, where `Framework` denotes the name of the framework and `header.h` is found in the `PrivateHeaders` or `Headers` directory.

`-iframework`*dir*
: Like `-F` except the directory is a treated as a system directory. The main difference between this `-iframework` and `-F` is that with `-iframework` the compiler does not warn about constructs contained within header files found via *dir*. This option is valid only for the C family of languages.

`-arch` *name*
: Generate output for architecture *name*. As described above, GCC generates output for the architecture it was configured for, using its usual options to

select subarchitecture variants. The `-arch` option is accepted for compatibility, but an error is diagnosed if *name* is inconsistent with GCC's own idea of the target architecture.

`-dependency-file filename`
: Alias for the preprocessor option `-MF filename`. See Section 3.14 [Preprocessor Options], page 297.

`-fapple-kext`
: Generate code for Darwin loadable kernel extensions.

`-gused`
: Emit debugging information for symbols that are used. For stabs debugging format, this enables `-feliminate-unused-debug-symbols`. This is by default ON.

`-gfull`
: Emit debugging information for all symbols and types.

`-matt-stubs`
`-mno-att-stubs`
: Enable AT&T-style PIC stubs. This is the default when supported by the target architecture (currently x86 only).

`-mconstant-cfstrings`
`-fconstant-cfstrings`
: When the NeXT runtime is being used (the default on these systems), override any `-fconstant-string-class` setting and cause `@"..."` literals to be laid out as constant CoreFoundation strings.

  `-fconstant-cfstrings` is an alias for `-mconstant-cfstrings`.

`-mdynamic-no-pic`
: Generate code suitable for executables (not shared libraries). This option is incompatible with `-fpic`, `-fPIC`, `-fpie`, or `-fPIE`.

`-mfix-and-continue`
`-ffix-and-continue`
`-findirect-data`
: Generate code suitable for fast turnaround development, such as to allow GDB to dynamically load `.o` files into already-running programs. `-findirect-data` and `-ffix-and-continue` are provided for backwards compatibility.

`-mkernel`
: Enable kernel development mode. The `-mkernel` option sets `-static`, `-fno-common`, `-fno-use-cxa-atexit`, `-fno-exceptions`, `-fno-non-call-exceptions`, `-fapple-kext`, `-fno-weak` and `-fno-rtti` where applicable. This mode also sets `-mno-altivec`, `-msoft-float`, `-fno-builtin` and `-mlong-branch` for PowerPC targets.

`-mmacosx-version-min=version`
`-asm_macosx_version_min=version`
: The `-mmacosx-version-min` option specifies the earliest version of MacOS X that this executable will run on is *version*. Typical values supported for *version* include `12`, `10.12`, and `10.5.8`.

  If the compiler was built to use the system's headers by default, then the default for this option is the system version on which the compiler is running, otherwise the default is to make choices that are compatible with as many systems and code bases as possible.

`-asm_macosx_version_min=`*version* is similar, but the GCC driver passes its *version* information only to the assembler.

`-mone-byte-bool`
: Override the defaults for `bool` so that `sizeof(bool)==1`. By default `sizeof(bool)` is `4` when compiling for Darwin/PowerPC and `1` when compiling for Darwin/x86, so this option has no effect on x86.

  Warning: The `-mone-byte-bool` switch causes GCC to generate code that is not binary compatible with code generated without that switch. Using this switch may require recompiling all other modules in a program, including system libraries. Use this switch to conform to a non-default data model.

`-msymbol-stubs`
`-mno-symbol-stubs`
: Force generation of external symbol indirection stubs for PIC references. By default, this option is enabled automatically if the target linker version (`-mtarget-linker`) is old enough to require them.

`-mtarget-linker=`*version*
`-mtarget-linker` *version*
: Specify the target `ld64` version, overriding any version specified in the GCC configuration. Newer linker versions support improved code generation in some cases, for example for PIC code.

`-ObjC`
: Equivalent to '`-x objective-c`'; specifies that the input is is Objective-C source code.

`-ObjC++`
: Equivalent to '`-x objective-c++`'; specifies that the input is is Objective-C++ source code.

`-Wnonportable-cfstrings`
`-Wno-nonportable-cfstrings`
: Warn if constant CoreFoundation string objects contain non-portable characters. This warning is enabled by default.

`-all_load`
: Loads all members of static archive libraries. See man ld(1) for more information.

`-arch_errors_fatal`
: Cause the errors having to do with files that have the wrong architecture to be fatal.

`-bind_at_load`
: Causes the output file to be marked such that the dynamic linker will bind all undefined references when the file is loaded or launched.

`-bundle`
: Produce a Mach-o bundle format file. See man ld(1) for more information.

`-bundle_loader` *executable*
: This option specifies the *executable* that will load the build output file being linked. See man ld(1) for more information.

`-dynamiclib`
: When passed this option, GCC produces a dynamic library instead of an executable when linking, using the Darwin `libtool` command.

`-force_cpusubtype_ALL`
: This causes GCC's output file to have the 'ALL' subtype, instead of one controlled by the `-mcpu` or `-march` option.

`-nodefaultrpaths`
: Do not add default run paths for the compiler library directories to executables, modules or dynamic libraries. On macOS 10.5 and later, the embedded runpath is added by default unless the user adds `-nodefaultrpaths` to the link line. Run paths are needed (and therefore enforced) to build on macOS version 10.11 or later.

`-nodefaultexport`
: Do not add default symbol exports to modules or dynamic libraries.

`-allowable_client` *client_name*
`-client_name`
`-compatibility_version`
`-current_version`
`-dead_strip`
`-dylib_file`
`-dylinker`
`-dylinker_install_name`
`-dynamic`
`-exported_symbols_list`
`-filelist`
`-flat_namespace`
`-force_flat_namespace`
`-framework`
`-headerpad_max_install_names`
`-image_base`
`-init` *symbol-name*
`-install_name`
`-keep_private_externs`
`-pagezero_size`
`-preload`
`-read_only_relocs`
`-sectalign`
`-sectcreate`
`-seg_addr_table`
`-seg1addr`
`-segaddr`
`-segprot`
`-segs_read_only_addr`
`-segs_read_write_addr`
`-sub_library`

-sub_umbrella
-twolevel_namespace
-twolevel_namespace_hints
-umbrella
-undefined
-unexported_symbols_list
-weak_framework
-weak_reference_mismatches
-whatsloaded
-whyload These options are passed to the Darwin linker. The Darwin linker man page describes them in detail.

3.20.13 DEC Alpha Options

These '-m' options are defined for the DEC Alpha implementations:

-mno-soft-float
-msoft-float
: Use (do not use) the hardware floating-point instructions for floating-point operations. When -msoft-float is specified, functions in libgcc.a are used to perform floating-point operations. Unless they are replaced by routines that emulate the floating-point operations, or compiled in such a way as to call such emulations routines, these routines issue floating-point operations. If you are compiling for an Alpha without floating-point operations, you must ensure that the library is built so as not to call them.

  Note that Alpha implementations without floating-point operations are required to have floating-point registers.

-mfp-reg
-mno-fp-regs
: Generate code that uses (does not use) the floating-point register set. -mno-fp-regs implies -msoft-float. If the floating-point register set is not used, floating-point operands are passed in integer registers as if they were integers and floating-point results are passed in $0 instead of $f0. This is a non-standard calling sequence, so any function with a floating-point argument or return value called by code compiled with -mno-fp-regs must also be compiled with that option.

  A typical use of this option is building a kernel that does not use, and hence need not save and restore, any floating-point registers.

-mieee The Alpha architecture implements floating-point hardware optimized for maximum performance. It is mostly compliant with the IEEE floating-point standard. However, for full compliance, software assistance is required. This option generates code fully IEEE-compliant code *except* that the *inexact-flag* is not maintained (see below). If this option is turned on, the preprocessor macro _IEEE_FP is defined during compilation. The resulting code is less efficient but is able to correctly support denormalized numbers and exceptional IEEE values such as not-a-number and plus/minus infinity. Other Alpha compilers call this option -ieee_with_no_inexact.

`-mieee-with-inexact`

This is like `-mieee` except the generated code also maintains the IEEE *inexact-flag*. Turning on this option causes the generated code to implement fully-compliant IEEE math. In addition to `_IEEE_FP`, `_IEEE_FP_EXACT` is defined as a preprocessor macro. On some Alpha implementations the resulting code may execute significantly slower than the code generated by default. Since there is very little code that depends on the *inexact-flag*, you should normally not specify this option. Other Alpha compilers call this option `-ieee_with_inexact`.

`-mfp-trap-mode=`*`trap-mode`*

This option controls what floating-point related traps are enabled. Other Alpha compilers call this option `-fptm` *`trap-mode`*. The trap mode can be set to one of four values:

‘`n`’ This is the default (normal) setting. The only traps that are enabled are the ones that cannot be disabled in software (e.g., division by zero trap).

‘`u`’ In addition to the traps enabled by ‘`n`’, underflow traps are enabled as well.

‘`su`’ Like ‘`u`’, but the instructions are marked to be safe for software completion (see Alpha architecture manual for details).

‘`sui`’ Like ‘`su`’, but inexact traps are enabled as well.

`-mfp-rounding-mode=`*`rounding-mode`*

Selects the IEEE rounding mode. Other Alpha compilers call this option `-fprm` *`rounding-mode`*. The *rounding-mode* can be one of:

‘`n`’ Normal IEEE rounding mode. Floating-point numbers are rounded towards the nearest machine number or towards the even machine number in case of a tie.

‘`m`’ Round towards minus infinity.

‘`c`’ Chopped rounding mode. Floating-point numbers are rounded towards zero.

‘`d`’ Dynamic rounding mode. A field in the floating-point control register (*fpcr*, see Alpha architecture reference manual) controls the rounding mode in effect. The C library initializes this register for rounding towards plus infinity. Thus, unless your program modifies the *fpcr*, ‘`d`’ corresponds to round towards plus infinity.

`-mtrap-precision=`*`trap-precision`*

In the Alpha architecture, floating-point traps are imprecise. This means without software assistance it is impossible to recover from a floating trap and program execution normally needs to be terminated. GCC can generate code that can assist operating system trap handlers in determining the exact location that caused a floating-point trap. Depending on the requirements of an application, different levels of precisions can be selected:

'p' Program precision. This option is the default and means a trap handler can only identify which program caused a floating-point exception.

'f' Function precision. The trap handler can determine the function that caused a floating-point exception.

'i' Instruction precision. The trap handler can determine the exact instruction that caused a floating-point exception.

Other Alpha compilers provide the equivalent options called `-scope_safe` and `-resumption_safe`.

`-mieee-conformant`
: This option marks the generated code as IEEE conformant. You must not use this option unless you also specify `-mtrap-precision=i` and either `-mfp-trap-mode=su` or `-mfp-trap-mode=sui`. Its only effect is to emit the line '`.eflag 48`' in the function prologue of the generated assembly file.

`-mbuild-constants`
: Normally GCC examines a 32- or 64-bit integer constant to see if it can construct it from smaller constants in two or three instructions. If it cannot, it outputs the constant as a literal and generates code to load it from the data segment at run time.

Use this option to require GCC to construct *all* integer constants using code, even if it takes more instructions (the maximum is six).

You typically use this option to build a shared library dynamic loader. Itself a shared library, it must relocate itself in memory before it can find the variables and constants in its own data segment.

`-mbwx`
`-mno-bwx`
`-mcix`
`-mno-cix`
`-mfix`
`-mno-fix`
`-mmax`
`-mno-max` Indicate whether GCC should generate code to use the optional BWX, CIX, FIX and MAX instruction sets. The default is to use the instruction sets supported by the CPU type specified via `-mcpu=` option or that of the CPU on which GCC was built if none is specified.

`-msafe-bwa`
`-mno-safe-bwa`
: Indicate whether in the absence of the optional BWX instruction set GCC should generate multi-thread and async-signal safe code for byte and aligned word memory accesses.

`-msafe-partial`
`-mno-safe-partial`
: Indicate whether GCC should generate multi-thread and async-signal safe code for partial memory accesses, including piecemeal accesses to unaligned data as

well as block accesses to leading and trailing parts of aggregate types or other objects in memory that do not respectively start and end on an aligned 64-bit data boundary.

`-mfloat-vax`
`-mfloat-ieee`
: Generate code that uses (does not use) VAX F and G floating-point arithmetic instead of IEEE single and double precision.

`-mexplicit-relocs`
`-mno-explicit-relocs`
: Older Alpha assemblers provided no way to generate symbol relocations except via assembler macros. Use of these macros does not allow optimal instruction scheduling. GNU Binutils as of version 2.12 supports a new syntax that allows the compiler to explicitly mark which relocations should apply to which instructions. This option is mostly useful for debugging, as GCC detects the capabilities of the assembler when it is built and sets the default accordingly.

`-msmall-data`
`-mlarge-data`
: When `-mexplicit-relocs` is in effect, static data is accessed via *gp-relative* relocations. When `-msmall-data` is used, objects 8 bytes long or smaller are placed in a *small data area* (the `.sdata` and `.sbss` sections) and are accessed via 16-bit relocations off of the `$gp` register. This limits the size of the small data area to 64KB, but allows the variables to be directly accessed via a single instruction.

  The default is `-mlarge-data`. With this option the data area is limited to just below 2GB. Programs that require more than 2GB of data must use `malloc` or `mmap` to allocate the data in the heap instead of in the program's data segment.

  When generating code for shared libraries, `-fpic` implies `-msmall-data` and `-fPIC` implies `-mlarge-data`.

`-msmall-text`
`-mlarge-text`
: When `-msmall-text` is used, the compiler assumes that the code of the entire program (or shared library) fits in 4MB, and is thus reachable with a branch instruction. When `-msmall-data` is used, the compiler can assume that all local symbols share the same `$gp` value, and thus reduce the number of instructions required for a function call from 4 to 1.

  The default is `-mlarge-text`.

`-mcpu=`*cpu_type*
: Set the instruction set and instruction scheduling parameters for machine type *cpu_type*. You can specify either the '`EV`' style name or the corresponding chip number. GCC supports scheduling parameters for the EV4, EV5 and EV6 family of processors and chooses the default values for the instruction set from the processor you specify. If you do not specify a processor type, GCC defaults to the processor on which the compiler was built.

  Supported values for *cpu_type* are

'ev4'
'ev45'
'21064' Schedules as an EV4 and has no instruction set extensions.

'ev5'
'21164' Schedules as an EV5 and has no instruction set extensions.

'ev56'
'21164a' Schedules as an EV5 and supports the BWX extension.

'pca56'
'21164pc'
'21164PC' Schedules as an EV5 and supports the BWX and MAX extensions.

'ev6'
'21264' Schedules as an EV6 and supports the BWX, FIX, and MAX extensions.

'ev67'
'21264a' Schedules as an EV6 and supports the BWX, CIX, FIX, and MAX extensions.

Native toolchains also support the value 'native', which selects the best architecture option for the host processor. `-mcpu=native` has no effect if GCC does not recognize the processor.

`-mtune=`*cpu_type*
Set only the instruction scheduling parameters for machine type *cpu_type*. The instruction set is not changed.

Native toolchains also support the value 'native', which selects the best architecture option for the host processor. `-mtune=native` has no effect if GCC does not recognize the processor.

`-mmemory-latency=`*time*
Sets the latency the scheduler should assume for typical memory references as seen by the application. This number is highly dependent on the memory access patterns used by the application and the size of the external cache on the machine.

Valid options for *time* are

'*number*' A decimal number representing clock cycles.

'L1'
'L2'
'L3'
'main' The compiler contains estimates of the number of clock cycles for "typical" EV4 & EV5 hardware for the Level 1, 2 & 3 caches (also called Dcache, Scache, and Bcache), as well as to main memory. Note that L3 is only valid for EV5.

`-mtls-kernel`
Emit `rdval` instead of `rduniq` for thread pointer.

`-mtls-size=`*bitsize*
: Specify bit size of immediate TLS offsets. Valid values for *bitsize* are 16, 32, and 64; it defaults to 32.

`-mlong-double-128`
`-mlong-double-64`
: Specify the size of the `long double` type. Note that `-mlong-double-128` is incompatible with VAX floating point.

3.20.14 eBPF Options

`-mframe-limit=`*bytes*
: This specifies the hard limit for frame sizes, in bytes. Currently, the value that can be specified should be less than or equal to '`32767`'. Defaults to whatever limit is imposed by the version of the Linux kernel targeted.

`-mbig-endian`
: Generate code for a big-endian target.

`-mlittle-endian`
: Generate code for a little-endian target. This is the default.

`-mjmpext`
`-mno-jmpext`
: Enable or disable generation of extra conditional-branch instructions. Enabled for CPU v2 and above.

`-mjmp32`
`-mno-jmp32`
: Enable or disable generation of 32-bit jump instructions. Enabled for CPU v3 and above.

`-malu32`
`-mno-alu32`
: Enable or disable generation of 32-bit ALU instructions. Enabled for CPU v3 and above.

`-mv3-atomics`
`-mno-v3-atomics`
: Enable or disable instructions for general atomic operations introduced in CPU v3. Enabled for CPU v3 and above.

`-mbswap`
`-mno-bswap`
: Enable or disable byte swap instructions. Enabled for CPU v4 and above.

`-msdiv`
`-mno-sdiv`
: Enable or disable signed division and modulus instructions. Enabled for CPU v4 and above.

`-msmov`
`-mno-smov`
Enable or disable sign-extending move and memory load instructions. Enabled for CPU v4 and above.

`-mcpu=`*version*
This specifies which version of the eBPF ISA to target. Newer versions may not be supported by all kernels. The default is '`v4`'.

Supported values for *version* are:

'`v1`' The first stable eBPF ISA with no special features or extensions.

'`v2`' Supports the jump extensions, as in `-mjmpext`.

'`v3`' All features of v2, plus:
- 32-bit jump operations, as in `-mjmp32`
- 32-bit ALU operations, as in `-malu32`
- general atomic operations, as in `-mv3-atomics`

'`v4`' All features of v3, plus:
- Byte swap instructions, as in `-mbswap`
- Signed division and modulus instructions, as in `-msdiv`
- Sign-extending move and memory load instructions, as in `-msmov`

`-mco-re`
`-mno-co-re`
Enable or disable BPF Compile Once - Run Everywhere (CO-RE) support. BPF CO-RE support is enabled by default when generating BTF debug information for the BPF target (`-gbtf`).

`-mxbpf` Generate code for an expanded version of BPF, which relaxes some of the restrictions imposed by the BPF architecture:
- Save and restore callee-saved registers at function entry and exit, respectively.

`-masm=`*dialect*
Outputs assembly instructions using eBPF selected *dialect*. The default is '`pseudoc`'.

Supported values for *dialect* are:

'`normal`' Outputs normal assembly dialect.

'`pseudoc`' Outputs pseudo-c assembly dialect.

`-minline-memops-threshold=`*bytes*
Specifies a size threshold in bytes at or below which memmove, memcpy and memset shall always be expanded inline. Operations dealing with sizes larger than this threshold would have to be implemented using a library call instead of being expanded inline, but since BPF doesn't allow libcalls, exceeding this threshold results in a compile-time error. The default is '`1024`' bytes.

3.20.15 FR30 Options

These options are defined specifically for the FR30 port.

`-msmall-model`
: Use the small address space model. This can produce smaller code, but it does assume that all symbolic values and addresses fit into a 20-bit range.

`-mno-lsim`
: Assume that runtime support has been provided and so there is no need to include the simulator library (`libsim.a`) on the linker command line.

3.20.16 FRV Options

`-mgpr-32`
: Only use the first 32 general-purpose registers.

`-mgpr-64`
: Use all 64 general-purpose registers.

`-mfpr-32`
: Use only the first 32 floating-point registers.

`-mfpr-64`
: Use all 64 floating-point registers.

`-mhard-float`
: Use hardware instructions for floating-point operations.

`-msoft-float`
: Use library routines for floating-point operations.

`-malloc-cc`
: Dynamically allocate condition code registers.

`-mfixed-cc`
: Do not try to dynamically allocate condition code registers, only use `icc0` and `fcc0`.

`-mdword`
`-mno-dword`
: Control whether the ABI uses double-word instructions.

`-mdouble`
`-mno-double`
: Enable or disable use of floating-point double instructions.

`-mmedia`
`-mno-media`
: Enable or disable use of media instructions.

`-mmuladd`
`-mno-muladd`
: Enable or disable use of multiply and add/subtract instructions.

-mfdpic

Select the FDPIC ABI, which uses function descriptors to represent pointers to functions. Without any PIC/PIE-related options, it implies -fPIE. With -fpic or -fpie, it assumes GOT entries and small data are within a 12-bit range from the GOT base address; with -fPIC or -fPIE, GOT offsets are computed with 32 bits. With a 'bfin-elf' target, this option implies -msim.

-minline-plt

Enable inlining of PLT entries in function calls to functions that are not known to bind locally. It has no effect without -mfdpic. It's enabled by default if optimizing for speed and compiling for shared libraries (i.e., -fPIC or -fpic), or when an optimization option such as -O3 or above is present in the command line.

-mTLS

Assume a large TLS segment when generating thread-local code.

-mtls

Do not assume a large TLS segment when generating thread-local code.

-mgprel-ro

Enable the use of GPREL relocations in the FDPIC ABI for data that is known to be in read-only sections. It's enabled by default, except for -fpic or -fpie: even though it may help make the global offset table smaller, it trades 1 instruction for 4. With -fPIC or -fPIE, it trades 3 instructions for 4, one of which may be shared by multiple symbols, and it avoids the need for a GOT entry for the referenced symbol, so it's more likely to be a win. If it is not, -mno-gprel-ro can be used to disable it.

-multilib-library-pic

Link with the (library, not FD) pic libraries. It's implied by -mlibrary-pic, as well as by -fPIC and -fpic without -mfdpic. You should never have to use it explicitly.

-mlinked-fp

Follow the EABI requirement of always creating a frame pointer whenever a stack frame is allocated. This option is enabled by default and can be disabled with -mno-linked-fp.

-mlong-calls

Use indirect addressing to call functions outside the current compilation unit. This allows the functions to be placed anywhere within the 32-bit address space.

-malign-labels

Try to align labels to an 8-byte boundary by inserting NOPs into the previous packet. This option only has an effect when VLIW packing is enabled. It doesn't create new packets; it merely adds NOPs to existing ones.

-mlibrary-pic

Generate position-independent EABI code.

`-macc-4`
: Use only the first four media accumulator registers.

`-macc-8`
: Use all eight media accumulator registers.

`-mpack`

`-mno-pack`
: Enable or disable packing VLIW instructions.

`-mno-eflags`
: Do not mark ABI switches in e_flags.

`-mcond-move`
`-mno-cond-move`
: Enable or disable the use of conditional-move instructions; it is enabled by default.

This switch is mainly for debugging the compiler and will likely be removed in a future version.

`-mscc`
`-mno-scc`
: Enable or disable the use of conditional set instructions; it is enabled by default.

This switch is mainly for debugging the compiler and will likely be removed in a future version.

`-mcond-exec`
`-mno-cond-exec`
: Enable or disable the use of conditional execution; it is enabled by default.

This switch is mainly for debugging the compiler and will likely be removed in a future version.

`-mvliw-branch`
`-mno-vliw-branch`
: Enable or disable an optimization pass to pack branches into VLIW instructions; it is enabled by default.

This switch is mainly for debugging the compiler and will likely be removed in a future version.

`-mmulti-cond-exec`
`-mno-multi-cond-exec`
: Enable or disable optimization of `&&` and `||` in conditional execution; it is enabled by default.

This switch is mainly for debugging the compiler and will likely be removed in a future version.

`-mnested-cond-exec`
`-mno-nested-cond-exec`
: Enable or disable nested conditional execution optimizations; it is enabled by default.

This switch is mainly for debugging the compiler and will likely be removed in a future version.

`-moptimize-membar`
`-mno-optimize-membar`
This switch removes redundant `membar` instructions from the compiler-generated code. It is enabled by default.

`-mtomcat-stats`
Cause gas to print out tomcat statistics.

`-mcpu=`*cpu*
Select the processor type for which to generate code. Possible values are '`frv`', '`fr550`', '`tomcat`', '`fr500`', '`fr450`', '`fr405`', '`fr400`', '`fr300`' and '`simple`'.

3.20.17 FT32 Options

These options are defined specifically for the FT32 port.

`-msim` Specifies that the program will be run on the simulator. This causes an alternate runtime startup and library to be linked. You must not use this option when generating programs that will run on real hardware; you must provide your own runtime library for whatever I/O functions are needed.

`-mnodiv` Do not use div and mod instructions.

`-mft32b` Enable use of the extended instructions of the FT32B processor.

`-mcompress`
Compress all code using the Ft32B code compression scheme.

`-mnopm` Do not generate code that reads program memory.

3.20.18 GNU/Linux Options

These '`-m`' options are defined for GNU/Linux targets:

`-mglibc` Use the GNU C library. This is the default except on '`*-*-linux-*uclibc*`', '`*-*-linux-*musl*`' and '`*-*-linux-*android*`' targets.

`-muclibc` Use uClibc C library. This is the default on '`*-*-linux-*uclibc*`' targets.

`-mmusl` Use the musl C library. This is the default on '`*-*-linux-*musl*`' targets.

`-mbionic` Use Bionic C library. This is the default on '`*-*-linux-*android*`' targets.

`-mandroid`
`-mno-android`
Compile code compatible with Android platform. This is the default on '`*-*-linux-*android*`' targets.

When compiling, this option enables `-mbionic`, `-fPIC`, `-fno-exceptions` and `-fno-rtti` by default. When linking, this option makes the GCC driver pass Android-specific options to the linker. Finally, this option causes the preprocessor macro `__ANDROID__` to be defined.

This option can be disabled completely with `-mno-android`.

`-tno-android-cc`
: Disable compilation effects of `-mandroid`, i.e., do not enable `-mbionic`, `-fPIC`, `-fno-exceptions` and `-fno-rtti` by default.

`-tno-android-ld`
: Disable linking effects of `-mandroid`, i.e., pass standard Linux linking options to the linker.

3.20.19 H8/300 Options

These '`-m`' options are defined for the H8/300 implementations:

`-mrelax`
: Shorten some address references at link time, when possible; uses the linker option `-relax`. See Section "`ld` and the H8/300" in *Using ld*, for a fuller description.

`-mh`
: Generate code for the H8/300H.

`-ms`
: Generate code for the H8S.

`-mn`
: Generate code for the H8S and H8/300H in the normal mode. This switch must be used either with `-mh` or `-ms`.

`-ms2600`
: Generate code for the H8S/2600. This switch must be used with `-ms`.

`-mexr`
: Extended registers are stored on stack before execution of function with monitor attribute. Default option is `-mexr`. This option is valid only for H8S targets.

`-mno-exr`
: Extended registers are not stored on stack before execution of function with monitor attribute. Default option is `-mno-exr`. This option is valid only for H8S targets.

`-mint32`
: Make `int` data 32 bits by default.

`-malign-300`
: On the H8/300H and H8S, use the same alignment rules as for the H8/300. The default for the H8/300H and H8S is to align longs and floats on 4-byte boundaries. `-malign-300` causes them to be aligned on 2-byte boundaries. This option has no effect on the H8/300.

3.20.20 HPPA Options

These '`-m`' options are defined for the HPPA family of computers:

`-march=`*`architecture-type`*
: Generate code for the specified architecture. The choices for *architecture-type* are '`1.0`' for PA 1.0, '`1.1`' for PA 1.1, and '`2.0`' for PA 2.0 processors. Refer to `/usr/lib/sched.models` on an HP-UX system to determine the proper architecture option for your machine. Code compiled for lower numbered architectures runs on higher numbered architectures, but not the other way around.

`-mpa-risc-1-0`
`-mpa-risc-1-1`
`-mpa-risc-2-0`
: Synonyms for `-march=1.0`, `-march=1.1`, and `-march=2.0` respectively.

`-matomic-libcalls`
Generate libcalls for atomic loads and stores when sync libcalls are disabled. This option is enabled by default. It only affects the generation of atomic libcalls by the HPPA backend.

Both the sync and `libatomic` libcall implementations use locking. As a result, processor stores are not atomic with respect to other atomic operations. Processor loads up to DImode are atomic with respect to other atomic operations provided they are implemented as a single access.

The PA-RISC architecture does not support any atomic operations in hardware except for the `ldcw` instruction. Thus, all atomic support is implemented using sync and atomic libcalls. Sync libcall support is in `libgcc.a`. Atomic libcall support is in `libatomic`.

This option generates `__atomic_exchange` calls for atomic stores. It also provides special handling for atomic DImode accesses on 32-bit targets.

`-mbig-switch`
Does nothing. Preserved for backward compatibility.

`-mcaller-copies`
The caller copies function arguments passed by hidden reference. This option should be used with care as it is not compatible with the default 32-bit runtime. However, only aggregates larger than eight bytes are passed by hidden reference and the option provides better compatibility with OpenMP.

`-mcoherent-ldcw`
Use ldcw/ldcd coherent cache-control hint.

`-mdisable-fpregs`
Disable floating-point registers. Equivalent to `-msoft-float`.

`-mdisable-indexing`
Prevent the compiler from using indexing address modes. This avoids some rather obscure problems when compiling MIG generated code under MACH.

`-mfast-indirect-calls`
Generate code that assumes calls never cross space boundaries. This allows GCC to emit code that performs faster indirect calls.

This option does not work in the presence of shared libraries or nested functions.

`-mfixed-range=`*`register-range`*
Generate code treating the given register range as fixed registers. A fixed register is one that the register allocator cannot use. This is useful when compiling kernel code. A register range is specified as two registers separated by a dash. Multiple register ranges can be specified separated by a comma.

`-mgas` Enable the use of assembler directives only GAS understands.

`-mgnu-ld` Use options specific to GNU `ld`. This passes `-shared` to `ld` when building a shared library. It is the default when GCC is configured, explicitly or implicitly, with the GNU linker. This option does not affect which `ld` is called; it only changes what parameters are passed to that `ld`. The `ld` that is called is determined by the `--with-ld` configure option, GCC's program search path, and finally by the user's `PATH`. The linker used by GCC can be printed using '`which `gcc -print-prog-name=ld``'. This option is only available on the 64-bit HP-UX GCC, i.e. configured with '`hppa*64*-*-hpux*`'.

`-mhp-ld`
: Use options specific to HP `ld`. This passes `-b` to `ld` when building a shared library and passes `+Accept TypeMismatch` to `ld` on all links. It is the default when GCC is configured, explicitly or implicitly, with the HP linker. This option does not affect which `ld` is called; it only changes what parameters are passed to that `ld`. The `ld` that is called is determined by the `--with-ld` configure option, GCC's program search path, and finally by the user's `PATH`. The linker used by GCC can be printed using '`which `gcc -print-prog-name=ld``'. This option is only available on the 64-bit HP-UX GCC, i.e. configured with '`hppa*64*-*-hpux*`'.

`-mlinker-opt`
: Enable the optimization pass in the HP-UX linker. Note this makes symbolic debugging impossible.

`-mlong-calls`
: Generate code that uses long call sequences. This ensures that a call is always able to reach linker generated stubs. The default is to generate long calls only when the distance from the call site to the beginning of the function or translation unit, as the case may be, exceeds a predefined limit set by the branch type being used. The limits for normal calls are 7,600,000 and 240,000 bytes, respectively for the PA 2.0 and PA 1.X architectures. Sibcalls are always limited at 240,000 bytes.

  Distances are measured from the beginning of functions when using the `-ffunction-sections` option, or when using the `-mgas` and `-mno-portable-runtime` options together under HP-UX with the SOM linker.

  It is normally not desirable to use this option as it degrades performance. However, it may be useful in large applications, particularly when partial linking is used to build the application.

  The types of long calls used depends on the capabilities of the assembler and linker, and the type of code being generated. The impact on systems that support long absolute calls, and long pic symbol-difference or pc-relative calls should be relatively small. However, an indirect call is used on 32-bit ELF systems in pic code and it is quite long.

`-mlong-load-store`
: Generate 3-instruction load and store sequences as sometimes required by the HP-UX 10 linker. This is equivalent to the '`+k`' option to the HP compilers.

`-mjump-in-delay`
: This option is ignored and provided for compatibility purposes only.

`-mno-space-regs`
: Generate code that assumes the target has no space registers. This allows GCC to generate faster indirect calls and use unscaled index address modes.

  Such code is suitable for level 0 PA systems and kernels.

`-mordered`
Assume memory references are ordered and barriers are not needed.

`-mportable-runtime`
Use the portable calling conventions proposed by HP for ELF systems.

`-mschedule=cpu-type`
Schedule code according to the constraints for the machine type *cpu-type*. The choices for *cpu-type* are '700' '7100', '7100LC', '7200', '7300' and '8000'. Refer to `/usr/lib/sched.models` on an HP-UX system to determine the proper scheduling option for your machine. The default scheduling is '8000'.

`-msio` Generate the predefine, `_SIO`, for server IO. The default is `-mwsio`. This generates the predefines, `__hp9000s700`, `__hp9000s700__` and `_WSIO`, for workstation IO. These options are available under HP-UX and HI-UX.

`-msoft-float`
Generate output containing library calls for floating point. **Warning:** the requisite libraries are not available for all HPPA targets. Normally the facilities of the machine's usual C compiler are used, but this cannot be done directly in cross-compilation. You must make your own arrangements to provide suitable library functions for cross-compilation.

`-msoft-float` changes the calling convention in the output file; therefore, it is only useful if you compile *all* of a program with this option. In particular, you need to compile `libgcc.a`, the library that comes with GCC, with `-msoft-float` in order for this to work.

`-msoft-mult`
Use software integer multiplication.

This disables the use of the `xmpyu` instruction.

`-munix=unix-std`
Generate compiler predefines and select a startfile for the specified UNIX standard. The choices for *unix-std* are '93', '95' and '98'. '93' is supported on all HP-UX versions. '95' is available on HP-UX 10.10 and later. '98' is available on HP-UX 11.11 and later. The default values are '93' for HP-UX 10.00, '95' for HP-UX 10.10 though to 11.00, and '98' for HP-UX 11.11 and later.

`-munix=93` provides the same predefines as GCC 3.3 and 3.4. `-munix=95` provides additional predefines for `XOPEN_UNIX` and `_XOPEN_SOURCE_EXTENDED`, and the startfile `unix95.o`. `-munix=98` provides additional predefines for `_XOPEN_UNIX`, `_XOPEN_SOURCE_EXTENDED`, `_INCLUDE__STDC_A1_SOURCE` and `_INCLUDE_XOPEN_SOURCE_500`, and the startfile `unix98.o`.

It is *important* to note that this option changes the interfaces for various library routines. It also affects the operational behavior of the C library. Thus, *extreme* care is needed in using this option.

Library code that is intended to operate with more than one UNIX standard must test, set and restore the variable `__xpg4_extended_mask` as appropriate. Most GNU software doesn't provide this capability.

`-nolibdld`
: Suppress the generation of link options to search libdld.sl when the `-static` option is specified on HP-UX 10 and later.

`-static`
: The HP-UX implementation of setlocale in libc has a dependency on libdld.sl. There isn't an archive version of libdld.sl. Thus, when the `-static` option is specified, special link options are needed to resolve this dependency.

  On HP-UX 10 and later, the GCC driver adds the necessary options to link with libdld.sl when the `-static` option is specified. This causes the resulting binary to be dynamic. On the 64-bit port, the linkers generate dynamic binaries by default in any case. The `-nolibdld` option can be used to prevent the GCC driver from adding these link options.

`-threads`
: Add support for multithreading with the *dce thread* library under HP-UX. This option sets flags for both the preprocessor and linker.

3.20.21 IA-64 Options

These are the '`-m`' options defined for the Intel IA-64 architecture.

`-mbig-endian`
: Generate code for a big-endian target. This is the default for HP-UX.

`-mlittle-endian`
: Generate code for a little-endian target. This is the default for AIX5 and GNU/Linux.

`-mgnu-as`
`-mno-gnu-as`
: Generate (or don't) code for the GNU assembler. This is the default.

`-mgnu-ld`
`-mno-gnu-ld`
: Generate (or don't) code for the GNU linker. This is the default.

`-mno-pic`
: Generate code that does not use a global pointer register. The result is not position independent code, and violates the IA-64 ABI.

`-mvolatile-asm-stop`
`-mno-volatile-asm-stop`
: Generate (or don't) a stop bit immediately before and after volatile asm statements.

`-mregister-names`
`-mno-register-names`
: Generate (or don't) '`in`', '`loc`', and '`out`' register names for the stacked registers. This may make assembler output more readable.

`-mno-sdata`
`-msdata`
: Disable (or enable) optimizations that use the small data section. This may be useful for working around optimizer bugs.

`-mconstant-gp`
: Generate code that uses a single constant global pointer value. This is useful when compiling kernel code.

`-mauto-pic`
: Generate code that is self-relocatable. This implies `-mconstant-gp`. This is useful when compiling firmware code.

`-minline-float-divide-min-latency`
: Generate code for inline divides of floating-point values using the minimum latency algorithm.

`-minline-float-divide-max-throughput`
: Generate code for inline divides of floating-point values using the maximum throughput algorithm.

`-mno-inline-float-divide`
: Do not generate inline code for divides of floating-point values.

`-minline-int-divide-min-latency`
: Generate code for inline divides of integer values using the minimum latency algorithm.

`-minline-int-divide-max-throughput`
: Generate code for inline divides of integer values using the maximum throughput algorithm.

`-mno-inline-int-divide`
: Do not generate inline code for divides of integer values.

`-minline-sqrt-min-latency`
: Generate code for inline square roots using the minimum latency algorithm.

`-minline-sqrt-max-throughput`
: Generate code for inline square roots using the maximum throughput algorithm.

`-mno-inline-sqrt`
: Do not generate inline code for `sqrt`.

`-mfused-madd`
`-mno-fused-madd`
: Do (don't) generate code that uses the fused multiply/add or multiply/subtract instructions. The default is to use these instructions.

`-mno-dwarf2-asm`
`-mdwarf2-asm`
: Don't (or do) generate assembler code for the DWARF line number debugging info. This may be useful when not using the GNU assembler.

`-mearly-stop-bits`
`-mno-early-stop-bits`
: Allow stop bits to be placed earlier than immediately preceding the instruction that triggered the stop bit. This can improve instruction scheduling, but does not always do so.

`-mfixed-range=`*`register-range`*
: Generate code treating the given register range as fixed registers. A fixed register is one that the register allocator cannot use. This is useful when compiling

kernel code. A register range is specified as two registers separated by a dash. Multiple register ranges can be specified separated by a comma.

`-mtls-size=`*`tls-size`*
: Specify bit size of immediate TLS offsets. Valid values are 14, 22, and 64.

`-mtune=`*`cpu-type`*
: Tune the instruction scheduling for a particular CPU, Valid values are '`itanium`', '`itanium1`', '`merced`', '`itanium2`', and '`mckinley`'.

`-milp32`
`-mlp64`
: Generate code for a 32-bit or 64-bit environment. The 32-bit environment sets int, long and pointer to 32 bits. The 64-bit environment sets int to 32 bits and long and pointer to 64 bits. These are HP-UX specific flags.

`-mno-sched-br-data-spec`
`-msched-br-data-spec`
: (Dis/En)able data speculative scheduling before reload. This results in generation of `ld.a` instructions and the corresponding check instructions (`ld.c` / `chk.a`). The default setting is disabled.

`-msched-ar-data-spec`
`-mno-sched-ar-data-spec`
: (En/Dis)able data speculative scheduling after reload. This results in generation of `ld.a` instructions and the corresponding check instructions (`ld.c` / `chk.a`). The default setting is enabled.

`-mno-sched-control-spec`
`-msched-control-spec`
: (Dis/En)able control speculative scheduling. This feature is available only during region scheduling (i.e. before reload). This results in generation of the `ld.s` instructions and the corresponding check instructions `chk.s`. The default setting is disabled.

`-msched-br-in-data-spec`
`-mno-sched-br-in-data-spec`
: (En/Dis)able speculative scheduling of the instructions that are dependent on the data speculative loads before reload. This is effective only with `-msched-br-data-spec` enabled. The default setting is enabled.

`-msched-ar-in-data-spec`
`-mno-sched-ar-in-data-spec`
: (En/Dis)able speculative scheduling of the instructions that are dependent on the data speculative loads after reload. This is effective only with `-msched-ar-data-spec` enabled. The default setting is enabled.

`-msched-in-control-spec`
`-mno-sched-in-control-spec`
: (En/Dis)able speculative scheduling of the instructions that are dependent on the control speculative loads. This is effective only with `-msched-control-spec` enabled. The default setting is enabled.

`-mno-sched-prefer-non-data-spec-insns`
`-msched-prefer-non-data-spec-insns`
If enabled, data-speculative instructions are chosen for schedule only if there are no other choices at the moment. This makes the use of the data speculation much more conservative. The default setting is disabled.

`-mno-sched-prefer-non-control-spec-insns`
`-msched-prefer-non-control-spec-insns`
If enabled, control-speculative instructions are chosen for schedule only if there are no other choices at the moment. This makes the use of the control speculation much more conservative. The default setting is disabled.

`-mno-sched-count-spec-in-critical-path`
`-msched-count-spec-in-critical-path`
If enabled, speculative dependencies are considered during computation of the instructions priorities. This makes the use of the speculation a bit more conservative. The default setting is disabled.

`-msched-spec-ldc`
Use a simple data speculation check. This option is on by default.

`-msched-control-spec-ldc`
Use a simple check for control speculation. This option is on by default.

`-msched-stop-bits-after-every-cycle`
Place a stop bit after every cycle when scheduling. This option is on by default.

`-msched-fp-mem-deps-zero-cost`
Assume that floating-point stores and loads are not likely to cause a conflict when placed into the same instruction group. This option is disabled by default.

`-msel-sched-dont-check-control-spec`
Generate checks for control speculation in selective scheduling. This flag is disabled by default.

`-msched-max-memory-insns=`*`max-insns`*
Limit on the number of memory insns per instruction group, giving lower priority to subsequent memory insns attempting to schedule in the same instruction group. Frequently useful to prevent cache bank conflicts. The default value is 1.

`-msched-max-memory-insns-hard-limit`
Makes the limit specified by `msched-max-memory-insns` a hard limit, disallowing more than that number in an instruction group. Otherwise, the limit is “soft”, meaning that non-memory operations are preferred when the limit is reached, but memory operations may still be scheduled.

3.20.22 LM32 Options

These `-m` options are defined for the LatticeMico32 architecture:

`-mbarrel-shift-enabled`
Enable barrel-shift instructions.

`-mdivide-enabled`
: Enable divide and modulus instructions.

`-mmultiply-enabled`
: Enable multiply instructions.

`-msign-extend-enabled`
: Enable sign extend instructions.

`-muser-enabled`
: Enable user-defined instructions.

3.20.23 LoongArch Options

These command-line options are defined for LoongArch targets:

`-march=`*`arch-type`*
: Generate instructions for the machine type *arch-type*. `-march=`*`arch-type`* allows GCC to generate code that may not run at all on processors other than the one indicated.

  The choices for *arch-type* are:

  '`native`' Local processor type detected by the native compiler.

  '`loongarch64`'
  Generic LoongArch 64-bit processor.

  '`la464`' LoongArch LA464-based processor with LSX, LASX.

  '`la664`' LoongArch LA664-based processor with LSX, LASX and all LoongArch v1.1 instructions.

  '`la64v1.0`'
  LoongArch64 ISA version 1.0.

  '`la64v1.1`'
  LoongArch64 ISA version 1.1.

  More information about LoongArch ISA versions can be found at `https://github.com/loongson/la-toolchain-conventions`.

`-mtune=`*`tune-type`*
: Optimize the generated code for the given processor target.

  The choices for *tune-type* are:

  '`native`' Local processor type detected by the native compiler.

  '`generic`' Generic LoongArch processor.

  '`loongarch64`'
  Generic LoongArch 64-bit processor.

  '`la464`' LoongArch LA464 core.

  '`la664`' LoongArch LA664 core.

`-mabi=base-abi-type`
Generate code for the specified calling convention. *base-abi-type* can be one of:

'`lp64d`' Uses 64-bit general purpose registers and 32/64-bit floating-point registers for parameter passing. Data model is LP64, where '`int`' is 32 bits, while '`long int`' and pointers are 64 bits.

'`lp64f`' Uses 64-bit general purpose registers and 32-bit floating-point registers for parameter passing. Data model is LP64, where '`int`' is 32 bits, while '`long int`' and pointers are 64 bits.

'`lp64s`' Uses 64-bit general purpose registers and no floating-point registers for parameter passing. Data model is LP64, where '`int`' is 32 bits, while '`long int`' and pointers are 64 bits.

`-mfpu=fpu-type`
Generate code for the specified FPU type, which can be one of:

'`64`' Allow the use of hardware floating-point instructions for 32-bit and 64-bit operations.

'`32`' Allow the use of hardware floating-point instructions for 32-bit operations.

'`none`'
'`0`' Prevent the use of hardware floating-point instructions.

`-msimd=simd-type`
Enable generation of LoongArch SIMD instructions for vectorization and via builtin functions. The value can be one of:

'`lasx`' Enable generating instructions from the 256-bit LoongArch Advanced SIMD Extension (LASX) and the 128-bit LoongArch SIMD Extension (LSX).

'`lsx`' Enable generating instructions from the 128-bit LoongArch SIMD Extension (LSX).

'`none`' No LoongArch SIMD instruction may be generated.

`-msoft-float`
Force `-mfpu=none` and prevents the use of floating-point registers for parameter passing. This option may change the target ABI.

`-msingle-float`
Force `-mfpu=32` and allow the use of 32-bit floating-point registers for parameter passing. This option may change the target ABI.

`-mdouble-float`
Force `-mfpu=64` and allow the use of 32/64-bit floating-point registers for parameter passing. This option may change the target ABI.

`-mlasx`
`-mno-lasx`
`-mlsx`
`-mno-lsx` Incrementally adjust the scope of the SIMD extensions (none / LSX / LASX) that can be used by the compiler for code generation. Enabling LASX with

`mlasx` automatically enables LSX, and diabling LSX with `mno-lsx` automatically disables LASX. These driver-only options act upon the final `msimd` configuration state and make incremental changes in the order they appear on the GCC driver's command line, deriving the final / canonicalized `msimd` option that is passed to the compiler proper.

`-mbranch-cost=n`
: Set the cost of branches to roughly *n* instructions.

`-maddr-reg-reg-cost=n`
: Set the cost of ADDRESS_REG_REG to the value calculated by *n*.

`-mcheck-zero-division`
`-mno-check-zero-divison`
: Trap (do not trap) on integer division by zero. The default is `-mcheck-zero-division` for `-O0` or `-Og`, and `-mno-check-zero-division` for other optimization levels.

`-mbreak-code=code`
: Emit a `break` *code* instruction for irrecoverable traps from `__builtin_trap` or inserted by the compiler (for example an erroneous path isolated with `-fisolate-erroneous-paths-dereference`), or an `amswap.w $r0, $r1, $r0` instruction which will cause the hardware to trigger an Instruction Not-defined Exception if *code* is negative or greater than 32767. The default is -1, meaning to use the `amswap.w` instruction.

`-mcond-move-int`
`-mno-cond-move-int`
: Conditional moves for integral data in general-purpose registers are enabled (disabled). The default is `-mcond-move-int`.

`-mcond-move-float`
`-mno-cond-move-float`
: Conditional moves for floating-point registers are enabled (disabled). The default is `-mcond-move-float`.

`-mmemcpy`
`-mno-memcpy`
: Force (do not force) the use of `memcpy` for non-trivial block moves. The default is `-mno-memcpy`, which allows GCC to inline most constant-sized copies. Setting optimization level to `-Os` also forces the use of `memcpy`, but `-mno-memcpy` may override this behavior if explicitly specified, regardless of the order these options on the command line.

`-mstrict-align`
`-mno-strict-align`
: Avoid or allow generating memory accesses that may not be aligned on a natural object boundary as described in the architecture specification. The default is `-mno-strict-align`.

`-G num`
: Put global and static data smaller than *num* bytes into a small data section. The default value is 0.

`-mmax-inline-memcpy-size=n`
: Inline all block moves (such as calls to `memcpy` or structure copies) less than or equal to *n* bytes. The default value of *n* is 1024.

`-mcmodel=code-model`
: Set the code model to one of:

  '`tiny-static (Not implemented yet)`'
  '`tiny (Not implemented yet)`'
  '`normal`' The text segment must be within 128MB addressing space. The data segment must be within 2GB addressing space.

  '`medium`' The text segment and data segment must be within 2GB addressing space. This is the default code model unless GCC has been configured with `--with-cmodel=` specifying a different default code model.

  '`large (Not implemented yet)`'
  '`extreme`' This mode does not limit the size of the code segment and data segment. The `-mcmodel=extreme` option is incompatible with `-fplt` and/or `-mexplicit-relocs=none`.

`-mexplicit-relocs=style`
: Set when to use assembler relocation operators when dealing with symbolic addresses. The alternative is to use assembler macros instead, which may limit instruction scheduling but allow linker relaxation. with `-mexplicit-relocs=none` the assembler macros are always used, with `-mexplicit-relocs=always` the assembler relocation operators are always used, with `-mexplicit-relocs=auto` the compiler will use the relocation operators where the linker relaxation is impossible to improve the code quality, and macros elsewhere. The default value for the option is determined with the assembler capability detected during GCC build-time and the setting of `-mrelax`: `-mexplicit-relocs=none` if the assembler does not support relocation operators at all, `-mexplicit-relocs=always` if the assembler supports relocation operators but `-mrelax` is not enabled, `-mexplicit-relocs=auto` if the assembler supports relocation operators and `-mrelax` is enabled.

`-mexplicit-relocs`
: An alias of `-mexplicit-relocs=always` for backward compatibility.

`-mno-explicit-relocs`
: An alias of `-mexplicit-relocs=none` for backward compatibility.

`-mdirect-extern-access`
`-mno-direct-extern-access`
: Do not use or use GOT to access external symbols. The default is `-mno-direct-extern-access`: GOT is used for external symbols with default visibility, but not used for other external symbols.

  With `-mdirect-extern-access`, GOT is not used and all external symbols are PC-relatively addressed. It is **only** suitable for environments where no dynamic link is performed, like firmwares, OS kernels, executables linked with `-static` or `-static-pie`. `-mdirect-extern-access` is not compatible with `-fPIC` or `-fpic`.

`-mrelax`
`-mno-relax`
: Take (do not take) advantage of linker relaxations. If `-mpass-mrelax-to-as` is enabled, this option is also passed to the assembler. The default is determined during GCC build-time by detecting corresponding assembler support: `-mrelax` if the assembler supports both the `-mrelax` option and the conditional branch relaxation (it's required or the `.align` directives and conditional branch instructions in the assembly code outputted by GCC may be rejected by the assembler because of a relocation overflow), `-mno-relax` otherwise.

`-mpass-mrelax-to-as`
`-mno-pass-mrelax-to-as`
: Pass (do not pass) the `-mrelax` or `-mno-relax` option to the assembler. The default is determined during GCC build-time by detecting corresponding assembler support: `-mpass-mrelax-to-as` if the assembler supports the `-mrelax` option, `-mno-pass-mrelax-to-as` otherwise. This option is mostly useful for debugging, or interoperation with assemblers different from the build-time one.

`-mrecip`
: This option enables use of the reciprocal estimate and reciprocal square root estimate instructions with additional Newton-Raphson steps to increase precision instead of doing a divide or square root and divide for floating-point arguments. These instructions are generated only when `-funsafe-math-optimizations` is enabled together with `-ffinite-math-only` and `-fno-trapping-math`. This option is off by default. Before you can use this option, you must sure the target CPU supports frecipe and frsqrte instructions. Note that while the throughput of the sequence is higher than the throughput of the non-reciprocal instruction, the precision of the sequence can be decreased by up to 2 ulp (i.e. the inverse of 1.0 equals 0.99999994).

`-mrecip=`*opt*
: This option controls which reciprocal estimate instructions may be used. *opt* is a comma-separated list of options, which may be preceded by a '`!`' to invert the option:

  '`all`' Enable all estimate instructions.

  '`default`' Enable the default instructions, equivalent to `-mrecip`.

  '`none`' Disable all estimate instructions, equivalent to `-mno-recip`.

  '`div`' Enable the approximation for scalar division.

  '`vec-div`' Enable the approximation for vectorized division.

  '`sqrt`' Enable the approximation for scalar square root.

  '`vec-sqrt`'
  Enable the approximation for vectorized square root.

  '`rsqrt`' Enable the approximation for scalar reciprocal square root.

'vec-rsqrt'
: Enable the approximation for vectorized reciprocal square root.

So, for example, -mrecip=all,!sqrt enables all of the reciprocal approximations, except for scalar square root.

-mfrecipe
-mno-frecipe
: Use (do not use) frecipe.{s/d} and frsqrte.{s/d} instructions. When build with -march=la664, it is enabled by default. The default is -mno-frecipe.

-mdiv32
-mno-div32
: Use (do not use) div.w[u] and mod.w[u] instructions with input not sign-extended. When build with -march=la664, it is enabled by default. The default is -mno-div32.

-mlam-bh
-mno-lam-bh
: Use (do not use) am{swap/add}[_db].{b/h} instructions. When build with -march=la664, it is enabled by default. The default is -mno-lam-bh.

-mlamcas
-mno-lamcas
: Use (do not use) amcas[_db].{b/h/w/d} instructions. When build with -march=la664, it is enabled by default. The default is -mno-lamcas.

-mld-seq-sa
-mno-ld-seq-sa
: Whether a same-address load-load barrier (dbar 0x700) is needed. When build with -march=la664, it is enabled by default. The default is -mno-ld-seq-sa, the load-load barrier is needed.

-mscq
-mno-scq
: Use (do not use) the 16-byte conditional store instruction sc.q. The default is -mscq if the machine type specified with -march= supports this instruction, -mno-scq otherwise.

-mtls-dialect=*opt*
: This option controls which tls dialect may be used for general dynamic and local dynamic TLS models.

'trad'
: Use traditional TLS. This is the default.

'desc'
: Use TLS descriptors.

-mannotate-tablejump
-mno-annotate-tablejump
: Create an annotation section .discard.tablejump_annotate to correlate the jirl instruction and the jump table when a jump table is used to optimize the switch statement. Some external tools, for example objtool of the Linux kernel building system, need the annotation to analysis the control flow. The default is -mno-annotate-tablejump.

`--param loongarch-vect-unroll-limit=n`
: The vectorizer will use available tuning information to determine whether it would be beneficial to unroll the main vectorized loop and by how much. This parameter set's the upper bound of how much the vectorizer will unroll the main loop. The default value is six.

3.20.24 M32C Options

`-mcpu=name`
: Select the CPU for which code is generated. *name* may be one of '`r8c`' for the R8C/Tiny series, '`m16c`' for the M16C (up to /60) series, '`m32cm`' for the M16C/80 series, or '`m32c`' for the M32C/80 series.

`-msim`
: Specifies that the program will be run on the simulator. This causes an alternate runtime library to be linked in which supports, for example, file I/O. You must not use this option when generating programs that will run on real hardware; you must provide your own runtime library for whatever I/O functions are needed.

`-memregs=number`
: Specifies the number of memory-based pseudo-registers GCC uses during code generation. These pseudo-registers are used like real registers, so there is a tradeoff between GCC's ability to fit the code into available registers, and the performance penalty of using memory instead of registers. Note that all modules in a program must be compiled with the same value for this option. Because of that, you must not use this option with GCC's default runtime libraries.

3.20.25 M32R/D Options

These `-m` options are defined for Renesas M32R/D architectures:

`-m32r2`
: Generate code for the M32R/2.

`-m32rx`
: Generate code for the M32R/X.

`-m32r`
: Generate code for the M32R. This is the default.

`-mmodel=small`
: Assume all objects live in the lower 16MB of memory (so that their addresses can be loaded with the `ld24` instruction), and assume all subroutines are reachable with the `bl` instruction. This is the default.

  The addressability of a particular object can be set with the `model` attribute.

`-mmodel=medium`
: Assume objects may be anywhere in the 32-bit address space (the compiler generates `seth/add3` instructions to load their addresses), and assume all subroutines are reachable with the `bl` instruction.

`-mmodel=large`
: Assume objects may be anywhere in the 32-bit address space (the compiler generates `seth/add3` instructions to load their addresses), and assume subroutines may not be reachable with the `bl` instruction (the compiler generates the much slower `seth/add3/jl` instruction sequence).

`-msdata=none`
: Disable use of the small data area. Variables are put into one of `.data`, `.bss`, or `.rodata` (unless the `section` attribute has been specified). This is the default.

  The small data area consists of sections `.sdata` and `.sbss`. Objects may be explicitly put in the small data area with the `section` attribute using one of these sections.

`-msdata=sdata`
: Put small global and static data in the small data area, but do not generate special code to reference them.

`-msdata=use`
: Put small global and static data in the small data area, and generate special instructions to reference them.

`-G num`
: Put global and static objects less than or equal to *num* bytes into the small data or BSS sections instead of the normal data or BSS sections. The default value of *num* is 8. The `-msdata` option must be set to one of '`sdata`' or '`use`' for this option to have any effect.

  All modules should be compiled with the same `-G num` value. Compiling with different values of *num* may or may not work; if it doesn't the linker gives an error message—incorrect code is not generated.

`-mdebug`
: Makes the M32R-specific code in the compiler display some statistics that might help in debugging programs.

`-malign-loops`
: Align all loops to a 32-byte boundary.

`-mno-align-loops`
: Do not enforce a 32-byte alignment for loops. This is the default.

`-missue-rate=number`
: Issue *number* instructions per cycle. *number* can only be 1 or 2.

`-mbranch-cost=number`
: *number* can only be 1 or 2. If it is 1 then branches are preferred over conditional code, if it is 2, then the opposite applies.

`-mflush-trap=number`
: Specifies the trap number to use to flush the cache. The default is 12. Valid numbers are between 0 and 15 inclusive.

`-mno-flush-trap`
: Specifies that the cache cannot be flushed by using a trap.

`-mflush-func=name`
: Specifies the name of the operating system function to call to flush the cache. The default is '`_flush_cache`', but a function call is only used if a trap is not available.

`-mno-flush-func`
: Indicates that there is no OS function for flushing the cache.

3.20.26 M680x0 Options

These are the '-m' options defined for M680x0 and ColdFire processors. The default settings depend on which architecture was selected when the compiler was configured; the defaults for the most common choices are given below.

-march=*arch*

Generate code for a specific M680x0 or ColdFire instruction set architecture. Permissible values of *arch* for M680x0 architectures are: '68000', '68010', '68020', '68030', '68040', '68060' and 'cpu32'. ColdFire architectures are selected according to Freescale's ISA classification and the permissible values are: 'isaa', 'isaaplus', 'isab' and 'isac'.

GCC defines a macro __mcf*arch*__ whenever it is generating code for a ColdFire target. The *arch* in this macro is one of the -march arguments given above.

When used together, -march and -mtune select code that runs on a family of similar processors but that is optimized for a particular microarchitecture.

-mcpu=*cpu*

Generate code for a specific M680x0 or ColdFire processor. The M680x0 *cpu*s are: '68000', '68010', '68020', '68030', '68040', '68060', '68302', '68332' and 'cpu32'. The ColdFire *cpu*s are given by the table below, which also classifies the CPUs into families:

Family	**'-mcpu' arguments**
'51'	'51' '51ac' '51ag' '51cn' '51em' '51je' '51jf' '51jg' '51jm' '51mm' '51qe' '51qm'
'5206'	'5202' '5204' '5206'
'5206e'	'5206e'
'5208'	'5207' '5208'
'5211a'	'5210a' '5211a'
'5213'	'5211' '5212' '5213'
'5216'	'5214' '5216'
'52235'	'52230' '52231' '52232' '52233' '52234' '52235'
'5225'	'5224' '5225'
'52259'	'52252' '52254' '52255' '52256' '52258' '52259'
'5235'	'5232' '5233' '5234' '5235' '523x'
'5249'	'5249'
'5250'	'5250'
'5271'	'5270' '5271'
'5272'	'5272'
'5275'	'5274' '5275'
'5282'	'5280' '5281' '5282' '528x'
'53017'	'53011' '53012' '53013' '53014' '53015' '53016' '53017'
'5307'	'5307'
'5329'	'5327' '5328' '5329' '532x'
'5373'	'5372' '5373' '537x'
'5407'	'5407'
'5475'	'5470' '5471' '5472' '5473' '5474' '5475' '547x' '5480' '5481' '5482' '5483' '5484' '5485'

`-mcpu=cpu` overrides `-march=arch` if *arch* is compatible with *cpu*. Other combinations of `-mcpu` and `-march` are rejected.

GCC defines the macro `__mcf_cpu_cpu` when ColdFire target *cpu* is selected. It also defines `__mcf_family_family`, where the value of *family* is given by the table above.

`-mtune=tune`
: Tune the code for a particular microarchitecture within the constraints set by `-march` and `-mcpu`. The M680x0 microarchitectures are: '`68000`', '`68010`', '`68020`', '`68030`', '`68040`', '`68060`' and '`cpu32`'. The ColdFire microarchitectures are: '`cfv1`', '`cfv2`', '`cfv3`', '`cfv4`' and '`cfv4e`'.

  You can also use `-mtune=68020-40` for code that needs to run relatively well on 68020, 68030 and 68040 targets. `-mtune=68020-60` is similar but includes 68060 targets as well. These two options select the same tuning decisions as `-m68020-40` and `-m68020-60` respectively.

  GCC defines the macros `__mcarch` and `__mcarch__` when tuning for 680x0 architecture *arch*. It also defines `mcarch` unless either `-ansi` or a non-GNU `-std` option is used. If GCC is tuning for a range of architectures, as selected by `-mtune=68020-40` or `-mtune=68020-60`, it defines the macros for every architecture in the range.

  GCC also defines the macro `__muarch__` when tuning for ColdFire microarchitecture *uarch*, where *uarch* is one of the arguments given above.

`-m68000`
`-mc68000`
: Generate output for a 68000. This is the default when the compiler is configured for 68000-based systems. It is equivalent to `-march=68000`.

  Use this option for microcontrollers with a 68000 or EC000 core, including the 68008, 68302, 68306, 68307, 68322, 68328 and 68356.

`-m68010`
: Generate output for a 68010. This is the default when the compiler is configured for 68010-based systems. It is equivalent to `-march=68010`.

`-m68020`
`-mc68020`
: Generate output for a 68020. This is the default when the compiler is configured for 68020-based systems. It is equivalent to `-march=68020`.

`-m68030`
: Generate output for a 68030. This is the default when the compiler is configured for 68030-based systems. It is equivalent to `-march=68030`.

`-m68040`
: Generate output for a 68040. This is the default when the compiler is configured for 68040-based systems. It is equivalent to `-march=68040`.

  This option inhibits the use of 68881/68882 instructions that have to be emulated by software on the 68040. Use this option if your 68040 does not have code to emulate those instructions.

`-m68060`
: Generate output for a 68060. This is the default when the compiler is configured for 68060-based systems. It is equivalent to `-march=68060`.

  This option inhibits the use of 68020 and 68881/68882 instructions that have to be emulated by software on the 68060. Use this option if your 68060 does not have code to emulate those instructions.

-mcpu32
: Generate output for a CPU32. This is the default when the compiler is configured for CPU32-based systems. It is equivalent to `-march=cpu32`.

  Use this option for microcontrollers with a CPU32 or CPU32+ core, including the 68330, 68331, 68332, 68333, 68334, 68336, 68340, 68341, 68349 and 68360.

-m5200
: Generate output for a 520X ColdFire CPU. This is the default when the compiler is configured for 520X-based systems. It is equivalent to `-mcpu=5206`, and is now deprecated in favor of that option.

  Use this option for microcontroller with a 5200 core, including the MCF5202, MCF5203, MCF5204 and MCF5206.

-m5206e
: Generate output for a 5206e ColdFire CPU. The option is now deprecated in favor of the equivalent `-mcpu=5206e`.

-m528x
: Generate output for a member of the ColdFire 528X family. The option is now deprecated in favor of the equivalent `-mcpu=528x`.

-m5307
: Generate output for a ColdFire 5307 CPU. The option is now deprecated in favor of the equivalent `-mcpu=5307`.

-m5407
: Generate output for a ColdFire 5407 CPU. The option is now deprecated in favor of the equivalent `-mcpu=5407`.

-mcfv4e
: Generate output for a ColdFire V4e family CPU (e.g. 547x/548x). This includes use of hardware floating-point instructions. The option is equivalent to `-mcpu=547x`, and is now deprecated in favor of that option.

-m68020-40
: Generate output for a 68040, without using any of the new instructions. This results in code that can run relatively efficiently on either a 68020/68881 or a 68030 or a 68040. The generated code does use the 68881 instructions that are emulated on the 68040.

  The option is equivalent to `-march=68020 -mtune=68020-40`.

-m68020-60
: Generate output for a 68060, without using any of the new instructions. This results in code that can run relatively efficiently on either a 68020/68881 or a 68030 or a 68040. The generated code does use the 68881 instructions that are emulated on the 68060.

  The option is equivalent to `-march=68020 -mtune=68020-60`.

-mhard-float
-m68881
: Generate floating-point instructions. This is the default for 68020 and above, and for ColdFire devices that have an FPU. It defines the macro `__HAVE_68881__` on M680x0 targets and `__mcffpu__` on ColdFire targets.

-msoft-float
: Do not generate floating-point instructions; use library calls instead. This is the default for 68000, 68010, and 68832 targets. It is also the default for ColdFire devices that have no FPU.

`-mdiv`
`-mno-div` Generate (do not generate) ColdFire hardware divide and remainder instructions. If `-march` is used without `-mcpu`, the default is "on" for ColdFire architectures and "off" for M680x0 architectures. Otherwise, the default is taken from the target CPU (either the default CPU, or the one specified by `-mcpu`). For example, the default is "off" for `-mcpu=5206` and "on" for `-mcpu=5206e`.

GCC defines the macro `__mcfhwdiv__` when this option is enabled.

`-mshort` Consider type `int` to be 16 bits wide, like `short int`. Additionally, parameters passed on the stack are also aligned to a 16-bit boundary even on targets whose API mandates promotion to 32-bit.

`-mno-short`
Do not consider type `int` to be 16 bits wide. This is the default.

`-mnobitfield`
`-mno-bitfield`
Do not use the bit-field instructions. The `-m68000`, `-mcpu32` and `-m5200` options imply `-mnobitfield`.

`-mbitfield`
Do use the bit-field instructions. The `-m68020` option implies `-mbitfield`. This is the default if you use a configuration designed for a 68020.

`-mrtd` Use a different function-calling convention, in which functions that take a fixed number of arguments return with the `rtd` instruction, which pops their arguments while returning. This saves one instruction in the caller since there is no need to pop the arguments there.

This calling convention is incompatible with the one normally used on Unix, so you cannot use it if you need to call libraries compiled with the Unix compiler.

Also, you must provide function prototypes for all functions that take variable numbers of arguments (including `printf`); otherwise incorrect code is generated for calls to those functions.

In addition, seriously incorrect code results if you call a function with too many arguments. (Normally, extra arguments are harmlessly ignored.)

The `rtd` instruction is supported by the 68010, 68020, 68030, 68040, 68060 and CPU32 processors, but not by the 68000 or 5200.

The default is `-mno-rtd`.

`-malign-int`
`-mno-align-int`
Control whether GCC aligns `int`, `long`, `long long`, `float`, `double`, and `long double` variables on a 32-bit boundary (`-malign-int`) or a 16-bit boundary (`-mno-align-int`). Aligning variables on 32-bit boundaries produces code that runs somewhat faster on processors with 32-bit busses at the expense of more memory.

Warning: if you use the `-malign-int` switch, GCC aligns structures containing the above types differently than most published application binary interface specifications for the m68k.

Use the pc-relative addressing mode of the 68000 directly, instead of using a global offset table. At present, this option implies `-fpic`, allowing at most a 16-bit offset for pc-relative addressing. `-fPIC` is not presently supported with `-mpcrel`, though this could be supported for 68020 and higher processors.

`-mno-strict-align`
`-mstrict-align`
Do not (do) assume that unaligned memory references are handled by the system.

`-msep-data`
Generate code that allows the data segment to be located in a different area of memory from the text segment. This allows for execute-in-place in an environment without virtual memory management. This option implies `-fPIC`.

`-mno-sep-data`
Generate code that assumes that the data segment follows the text segment. This is the default.

`-mid-shared-library`
Generate code that supports shared libraries via the library ID method. This allows for execute-in-place and shared libraries in an environment without virtual memory management. This option implies `-fPIC`.

`-mno-id-shared-library`
Generate code that doesn't assume ID-based shared libraries are being used. This is the default.

`-mshared-library-id=n`
Specifies the identification number of the ID-based shared library being compiled. Specifying a value of 0 generates more compact code; specifying other values forces the allocation of that number to the current library, but is no more space- or time-efficient than omitting this option.

`-mxgot`
`-mno-xgot`
When generating position-independent code for ColdFire, generate code that works if the GOT has more than 8192 entries. This code is larger and slower than code generated without this option. On M680x0 processors, this option is not needed; `-fPIC` suffices.

GCC normally uses a single instruction to load values from the GOT. While this is relatively efficient, it only works if the GOT is smaller than about 64k. Anything larger causes the linker to report an error such as:

```
relocation truncated to fit: R_68K_GOT16O foobar
```

If this happens, you should recompile your code with `-mxgot`. It should then work with very large GOTs. However, code generated with `-mxgot` is less efficient, since it takes 4 instructions to fetch the value of a global symbol.

Note that some linkers, including newer versions of the GNU linker, can create multiple GOTs and sort GOT entries. If you have such a linker, you should only need to use `-mxgot` when compiling a single object file that accesses more than 8192 GOT entries. Very few do.

These options have no effect unless GCC is generating position-independent code.

`-mlong-jump-table-offsets`
Use 32-bit offsets in `switch` tables. The default is to use 16-bit offsets.

3.20.27 MCore Options

These are the '`-m`' options defined for the Motorola M*Core processors.

`-mhardlit`
`-mno-hardlit`
Inline constants into the code stream if it can be done in two instructions or less.

`-mdiv`
`-mno-div` Use the divide instruction. (Enabled by default).

`-mrelax-immediate`
`-mno-relax-immediate`
Allow arbitrary-sized immediates in bit operations.

`-mwide-bitfields`
`-mno-wide-bitfields`
Always treat bit-fields as `int`-sized.

`-m4byte-functions`
`-mno-4byte-functions`
Force all functions to be aligned to a 4-byte boundary.

`-mcallgraph-data`
`-mno-callgraph-data`
Emit callgraph information.

`-mslow-bytes`
`-mno-slow-bytes`
Prefer word access when reading byte quantities.

`-mlittle-endian`
`-mbig-endian`
Generate code for a little-endian target.

`-m210`
`-m340` Generate code for the 210 processor.

`-mno-lsim`
Assume that runtime support has been provided and so omit the simulator library (`libsim.a)` from the linker command line.

`-mstack-increment=`*`size`*
Set the maximum amount for a single stack increment operation. Large values can increase the speed of programs that contain functions that need a large amount of stack space, but they can also trigger a segmentation fault if the stack is extended too much. The default value is 0x1000.

3.20.28 MicroBlaze Options

`-msoft-float`
: Use software emulation for floating point (default).

`-mhard-float`
: Use hardware floating-point instructions.

`-mmemcpy`
: Do not optimize block moves, use `memcpy`.

`-mno-clearbss`
: This option is deprecated. Use `-fno-zero-initialized-in-bss` instead.

`-mcpu=cpu-type`
: Use features of, and schedule code for, the given CPU. Supported values are in the format '`vX.YY.Z`', where *X* is a major version, *YY* is the minor version, and *Z* is compatibility code. Example values are '`v3.00.a`', '`v4.00.b`', '`v5.00.a`', '`v5.00.b`', '`v6.00.a`'.

`-mxl-soft-mul`
: Use software multiply emulation (default).

`-mxl-soft-div`
: Use software emulation for divides (default).

`-mxl-barrel-shift`
: Use the hardware barrel shifter.

`-mxl-pattern-compare`
: Use pattern compare instructions.

`-msmall-divides`
: Use table lookup optimization for small signed integer divisions.

`-mxl-stack-check`
: This option is deprecated. Use `-fstack-check` instead.

`-mxl-gp-opt`
: Use GP-relative `.sdata`/`.sbss` sections.

`-mxl-multiply-high`
: Use multiply high instructions for high part of 32x32 multiply.

`-mxl-float-convert`
: Use hardware floating-point conversion instructions.

`-mxl-float-sqrt`
: Use hardware floating-point square root instruction.

`-mbig-endian`
: Generate code for a big-endian target.

`-mlittle-endian`
: Generate code for a little-endian target.

`-mxl-reorder`
: Use reorder instructions (swap and byte reversed load/store).

`-mxl-mode-app-model`
Select application model *app-model*. Valid models are

'`executable`'
normal executable (default), uses startup code `crt0.o`.

'`xmdstub`'
for use with Xilinx Microprocessor Debugger (XMD) based software intrusive debug agent called xmdstub. This uses startup file `crt1.o` and sets the start address of the program to 0x800.

'`bootstrap`'
for applications that are loaded using a bootloader. This model uses startup file `crt2.o` which does not contain a processor reset vector handler. This is suitable for transferring control on a processor reset to the bootloader rather than the application.

'`novectors`'
for applications that do not require any of the MicroBlaze vectors. This option may be useful for applications running within a monitoring application. This model uses `crt3.o` as a startup file.

Option `-xl-mode-app-model` is a deprecated alias for `-mxl-mode-app-model`.

`-mpic-data-is-text-relative`
Assume that the displacement between the text and data segments is fixed at static link time. This allows data to be referenced by offset from start of text address instead of GOT since PC-relative addressing is not supported.

3.20.29 MIPS Options

`-EB` Generate big-endian code.

`-EL` Generate little-endian code. This is the default for '`mips*el-*-*`' configurations.

`-march=arch`
Generate code that runs on *arch*, which can be the name of a generic MIPS ISA, or the name of a particular processor. The ISA names are: '`mips1`', '`mips2`', '`mips3`', '`mips4`', '`mips32`', '`mips32r2`', '`mips32r3`', '`mips32r5`', '`mips32r6`', '`mips64`', '`mips64r2`', '`mips64r3`', '`mips64r5`' and '`mips64r6`'. The processor names are: '`4kc`', '`4km`', '`4kp`', '`4ksc`', '`4kec`', '`4kem`', '`4kep`', '`4ksd`', '`5kc`', '`5kf`', '`20kc`', '`24kc`', '`24kf2_1`', '`24kf1_1`', '`24kec`', '`24kef2_1`', '`24kef1_1`', '`34kc`', '`34kf2_1`', '`34kf1_1`', '`34kn`', '`74kc`', '`74kf2_1`', '`74kf1_1`', '`74kf3_2`', '`1004kc`', '`1004kf2_1`', '`1004kf1_1`', '`i6400`', '`i6500`', '`interaptiv`', '`loongson2e`', '`loongson2f`', '`loongson3a`', '`gs464`', '`gs464e`', '`gs264e`', '`m4k`', '`m14k`', '`m14kc`', '`m14ke`', '`m14kec`', '`m5100`', '`m5101`', '`octeon`', '`octeon+`', '`octeon2`', '`octeon3`', '`orion`', '`p5600`', '`p6600`', '`r2000`', '`r3000`', '`r3900`', '`r4000`', '`r4400`', '`r4600`', '`r4650`', '`r4700`', '`r5900`', '`r6000`', '`r8000`', '`rm7000`', '`rm9000`', '`r10000`', '`r12000`', '`r14000`', '`r16000`', '`sb1`', '`sr71000`', '`vr4100`', '`vr4111`', '`vr4120`', '`vr4130`', '`vr4300`', '`vr5000`', '`vr5400`', '`vr5500`', '`xlr`' and '`xlp`'. '`allegrex`', The special value '`from-abi`' selects the most compatible

architecture for the selected ABI (that is, 'mips1' for 32-bit ABIs and 'mips3' for 64-bit ABIs).

The native Linux/GNU toolchain also supports the value 'native', which selects the best architecture option for the host processor. -march=native has no effect if GCC does not recognize the processor.

In processor names, a final '000' can be abbreviated as 'k' (for example, -march=r2k). Prefixes are optional, and 'vr' may be written 'r'.

Names of the form '*n*f2_1' refer to processors with FPUs clocked at half the rate of the core, names of the form '*n*f1_1' refer to processors with FPUs clocked at the same rate as the core, and names of the form '*n*f3_2' refer to processors with FPUs clocked a ratio of 3:2 with respect to the core. For compatibility reasons, '*n*f' is accepted as a synonym for '*n*f2_1' while '*n*x' and '*b*fx' are accepted as synonyms for '*n*f1_1'.

GCC defines two macros based on the value of this option. The first is _MIPS_ARCH, which gives the name of target architecture, as a string. The second has the form _MIPS_ARCH_*foo*, where *foo* is the capitalized value of _MIPS_ARCH. For example, -march=r2000 sets _MIPS_ARCH to "r2000" and defines the macro _MIPS_ARCH_R2000.

Note that the _MIPS_ARCH macro uses the processor names given above. In other words, it has the full prefix and does not abbreviate '000' as 'k'. In the case of 'from-abi', the macro names the resolved architecture (either "mips1" or "mips3"). It names the default architecture when no -march option is given.

-mtune=*arch*
: Optimize for *arch*. Among other things, this option controls the way instructions are scheduled, and the perceived cost of arithmetic operations. The list of *arch* values is the same as for -march.

  When this option is not used, GCC optimizes for the processor specified by -march. By using -march and -mtune together, it is possible to generate code that runs on a family of processors, but optimize the code for one particular member of that family.

  -mtune defines the macros _MIPS_TUNE and _MIPS_TUNE_*foo*, which work in the same way as the -march ones described above.

-mips1
: Equivalent to -march=mips1.

-mips2
: Equivalent to -march=mips2.

-mips3
: Equivalent to -march=mips3.

-mips4
: Equivalent to -march=mips4.

-mips32
: Equivalent to -march=mips32.

-mips32r3
: Equivalent to -march=mips32r3.

-mips32r5
: Equivalent to -march=mips32r5.

-mips32r6
: Equivalent to -march=mips32r6.

-mips64
: Equivalent to -march=mips64.

-mips64r2
: Equivalent to -march=mips64r2.

-mips64r3
: Equivalent to -march=mips64r3.

-mips64r5
: Equivalent to -march=mips64r5.

-mips64r6
: Equivalent to -march=mips64r6.

-mips16
-mno-mips16
: Generate (do not generate) MIPS16 code. If GCC is targeting a MIPS32 or MIPS64 architecture, it makes use of the MIPS16e ASE.

MIPS16 code generation can also be controlled on a per-function basis by means of mips16 and nomips16 attributes. See Section 6.4.1 [Function Attributes], page 621, for more information.

-mmips16e2
-mno-mips16e2
: Use (do not use) the MIPS16e2 ASE. This option modifies the behavior of the -mips16 option such that it targets the MIPS16e2 ASE.

-mflip-mips16
: Generate MIPS16 code on alternating functions. This option is provided for regression testing of mixed MIPS16/non-MIPS16 code generation, and is not intended for ordinary use in compiling user code.

-minterlink-compressed
-mno-interlink-compressed
: Require (do not require) that code using the standard (uncompressed) MIPS ISA be link-compatible with MIPS16 and microMIPS code, and vice versa.

For example, code using the standard ISA encoding cannot jump directly to MIPS16 or microMIPS code; it must either use a call or an indirect jump. -minterlink-compressed therefore disables direct jumps unless GCC knows that the target of the jump is not compressed.

-minterlink-mips16
-mno-interlink-mips16
: Aliases of -minterlink-compressed and -mno-interlink-compressed. These options predate the microMIPS ASE and are retained for backwards compatibility.

`-mabi=32`
`-mabi=o64`
`-mabi=n32`
`-mabi=64`
`-mabi=eabi`

Generate code for the given ABI.

Note that the EABI has a 32-bit and a 64-bit variant. GCC normally generates 64-bit code when you select a 64-bit architecture, but you can use `-mgp32` to get 32-bit code instead.

For information about the O64 ABI, see `https://gcc.gnu.org/projects/mipso64-abi.html`.

GCC supports a variant of the o32 ABI in which floating-point registers are 64 rather than 32 bits wide. You can select this combination with `-mabi=32 -mfp64`. This ABI relies on the `mthc1` and `mfhc1` instructions and is therefore only supported for MIPS32R2, MIPS32R3 and MIPS32R5 processors.

The register assignments for arguments and return values remain the same, but each scalar value is passed in a single 64-bit register rather than a pair of 32-bit registers. For example, scalar floating-point values are returned in '`$f0`' only, not a '`$f0`'/'`$f1`' pair. The set of call-saved registers also remains the same in that the even-numbered double-precision registers are saved.

Two additional variants of the o32 ABI are supported to enable a transition from 32-bit to 64-bit registers. These are FPXX (`-mfpxx`) and FP64A (`-mfp64 -mno-odd-spreg`). The FPXX extension mandates that all code must execute correctly when run using 32-bit or 64-bit registers. The code can be interlinked with either FP32 or FP64, but not both. The FP64A extension is similar to the FP64 extension but forbids the use of odd-numbered single-precision registers. This can be used in conjunction with the `FRE` mode of FPUs in MIPS32R5 processors and allows both FP32 and FP64A code to interlink and run in the same process without changing FPU modes.

`-mabicalls`
`-mno-abicalls`

Generate (do not generate) code that is suitable for SVR4-style dynamic objects. `-mabicalls` is the default for SVR4-based systems.

`-mshared`
`-mno-shared`

Generate (do not generate) code that is fully position-independent, and that can therefore be linked into shared libraries. This option only affects `-mabicalls`.

All `-mabicalls` code has traditionally been position-independent, regardless of options like `-fPIC` and `-fpic`. However, as an extension, the GNU toolchain allows executables to use absolute accesses for locally-binding symbols. It can also use shorter GP initialization sequences and generate direct calls to locally-defined functions. This mode is selected by `-mno-shared`.

`-mno-shared` depends on binutils 2.16 or higher and generates objects that can only be linked by the GNU linker. However, the option does not affect the ABI of the final executable; it only affects the ABI of relocatable objects. Using `-mno-shared` generally makes executables both smaller and quicker.

`-mshared` is the default.

`-mplt`
`-mno-plt` Assume (do not assume) that the static and dynamic linkers support PLTs and copy relocations. This option only affects `-mno-shared -mabicalls`. For the n64 ABI, this option has no effect without `-msym32`.

You can make `-mplt` the default by configuring GCC with `--with-mips-plt`. The default is `-mno-plt` otherwise.

`-mxgot`
`-mno-xgot`
Lift (do not lift) the usual restrictions on the size of the global offset table.

GCC normally uses a single instruction to load values from the GOT. While this is relatively efficient, it only works if the GOT is smaller than about 64k. Anything larger causes the linker to report an error such as:

```
relocation truncated to fit: R_MIPS_GOT16 foobar
```

If this happens, you should recompile your code with `-mxgot`. This works with very large GOTs, although the code is also less efficient, since it takes three instructions to fetch the value of a global symbol.

Note that some linkers can create multiple GOTs. If you have such a linker, you should only need to use `-mxgot` when a single object file accesses more than 64k's worth of GOT entries. Very few do.

These options have no effect unless GCC is generating position independent code.

`-mgp32` Assume that general-purpose registers are 32 bits wide.

`-mgp64` Assume that general-purpose registers are 64 bits wide.

`-mfp32` Assume that floating-point registers are 32 bits wide.

`-mfp64` Assume that floating-point registers are 64 bits wide.

`-mfpxx` Do not assume the width of floating-point registers.

`-mhard-float`
Use floating-point coprocessor instructions.

`-msoft-float`
Do not use floating-point coprocessor instructions. Implement floating-point calculations using library calls instead.

`-mno-float`
Equivalent to `-msoft-float`, but additionally asserts that the program being compiled does not perform any floating-point operations. This option is presently supported only by some bare-metal MIPS configurations, where it may select a special set of libraries that lack all floating-point support (including, for example, the floating-point `printf` formats). If code compiled with `-mno-float` accidentally contains floating-point operations, it is likely to suffer a link-time or run-time failure.

`-msingle-float`
: Assume that the floating-point coprocessor only supports single-precision operations.

`-mdouble-float`
: Assume that the floating-point coprocessor supports double-precision operations. This is the default.

`-modd-spreg`
`-mno-odd-spreg`
: Enable the use of odd-numbered single-precision floating-point registers for the o32 ABI. This is the default for processors that are known to support these registers. When using the o32 FPXX ABI, `-mno-odd-spreg` is set by default.

`-mabs=2008`
`-mabs=legacy`
: These options control the treatment of the special not-a-number (NaN) IEEE 754 floating-point data with the `abs.`*`fmt`* and `neg.`*`fmt`* machine instructions.

  By default or when `-mabs=legacy` is used the legacy treatment is selected. In this case these instructions are considered arithmetic and avoided where correct operation is required and the input operand might be a NaN. A longer sequence of instructions that manipulate the sign bit of floating-point datum manually is used instead unless the `-ffinite-math-only` option has also been specified.

  The `-mabs=2008` option selects the IEEE 754-2008 treatment. In this case these instructions are considered non-arithmetic and therefore operating correctly in all cases, including in particular where the input operand is a NaN. These instructions are therefore always used for the respective operations.

`-mnan=2008`
`-mnan=legacy`
: These options control the encoding of the special not-a-number (NaN) IEEE 754 floating-point data.

  The `-mnan=legacy` option selects the legacy encoding. In this case quiet NaNs (qNaNs) are denoted by the first bit of their trailing significand field being 0, whereas signaling NaNs (sNaNs) are denoted by the first bit of their trailing significand field being 1.

  The `-mnan=2008` option selects the IEEE 754-2008 encoding. In this case qNaNs are denoted by the first bit of their trailing significand field being 1, whereas sNaNs are denoted by the first bit of their trailing significand field being 0.

  The default is `-mnan=legacy` unless GCC has been configured with `--with-nan=2008`.

`-mllsc`
`-mno-llsc`
: Use (do not use) '`ll`', '`sc`', and '`sync`' instructions to implement atomic memory built-in functions. When neither option is specified, GCC uses the instructions if the target architecture supports them.

  `-mllsc` is useful if the runtime environment can emulate the instructions and `-mno-llsc` can be useful when compiling for nonstandard ISAs. You can make either option the default by configuring GCC with `--with-llsc` and `--without-llsc` respectively. `--with-llsc` is the default for some configurations; see the installation documentation for details.

`-mdsp`
`-mno-dsp` Use (do not use) revision 1 of the MIPS DSP ASE. See Section 7.13.15 [MIPS DSP Built-in Functions], page 927. This option defines the preprocessor macro `__mips_dsp`. It also defines `__mips_dsp_rev` to 1.

`-mdspr2`
`-mno-dspr2`
Use (do not use) revision 2 of the MIPS DSP ASE. See Section 7.13.15 [MIPS DSP Built-in Functions], page 927. This option defines the preprocessor macros `__mips_dsp` and `__mips_dspr2`. It also defines `__mips_dsp_rev` to 2.

`-msmartmips`
`-mno-smartmips`
Use (do not use) the MIPS SmartMIPS ASE.

`-mpaired-single`
`-mno-paired-single`
Use (do not use) paired-single floating-point instructions. See Section 7.13.16 [MIPS Paired-Single Support], page 931. This option requires hardware floating-point support to be enabled.

`-mdmx`
`-mno-mdmx`
Use (do not use) MIPS Digital Media Extension instructions. This option can only be used when generating 64-bit code and requires hardware floating-point support to be enabled.

`-mips3d`
`-mno-mips3d`
Use (do not use) the MIPS-3D ASE. See Section 7.13.17.3 [MIPS-3D Built-in Functions], page 935. The option `-mips3d` implies `-mpaired-single`.

`-mmicromips`
`-mno-micromips`
Generate (do not generate) microMIPS code.

MicroMIPS code generation can also be controlled on a per-function basis by means of `micromips` and `nomicromips` attributes. See Section 6.4.1 [Function Attributes], page 621, for more information.

`-mmt`
`-mno-mt` Use (do not use) MT Multithreading instructions.

`-mmcu`
`-mno-mcu` Use (do not use) the MIPS MCU ASE instructions.

`-meva`
`-mno-eva` Use (do not use) the MIPS Enhanced Virtual Addressing instructions.

`-mvirt`
`-mno-virt`
Use (do not use) the MIPS Virtualization (VZ) instructions.

`-mxpa`
`-mno-xpa` Use (do not use) the MIPS eXtended Physical Address (XPA) instructions.

`-mcrc`
`-mno-crc` Use (do not use) the MIPS Cyclic Redundancy Check (CRC) instructions.

`-mginv`
`-mno-ginv`
Use (do not use) the MIPS Global INValidate (GINV) instructions.

`-mloongson-mmi`
`-mno-loongson-mmi`
Use (do not use) the MIPS Loongson MultiMedia extensions Instructions (MMI).

`-mloongson-ext`
`-mno-loongson-ext`
Use (do not use) the MIPS Loongson EXTensions (EXT) instructions.

`-mloongson-ext2`
`-mno-loongson-ext2`
Use (do not use) the MIPS Loongson EXTensions r2 (EXT2) instructions.

`-mlong64` Force `long` types to be 64 bits wide. See `-mlong32` for an explanation of the default and the way that the pointer size is determined.

`-mlong32` Force `long`, `int`, and pointer types to be 32 bits wide.

The default size of `int`s, `long`s and pointers depends on the ABI. All the supported ABIs use 32-bit `int`s. The n64 ABI uses 64-bit `long`s, as does the 64-bit EABI; the others use 32-bit `long`s. Pointers are the same size as `long`s, or the same size as integer registers, whichever is smaller.

`-msym32`
`-mno-sym32`
Assume (do not assume) that all symbols have 32-bit values, regardless of the selected ABI. This option is useful in combination with `-mabi=64` and `-mno-abicalls` because it allows GCC to generate shorter and faster references to symbolic addresses.

`-G` *num* Put definitions of externally-visible data in a small data section if that data is no bigger than *num* bytes. GCC can then generate more efficient accesses to the data; see `-mgpopt` for details.

The default `-G` option depends on the configuration.

`-mlocal-sdata`
`-mno-local-sdata`
Extend (do not extend) the `-G` behavior to local data too, such as to static variables in C. `-mlocal-sdata` is the default for all configurations.

If the linker complains that an application is using too much small data, you might want to try rebuilding the less performance-critical parts with `-mno-local-sdata`. You might also want to build large libraries with `-mno-local-sdata`, so that the libraries leave more room for the main program.

`-mextern-sdata`
`-mno-extern-sdata`
Assume (do not assume) that externally-defined data is in a small data section if the size of that data is within the `-G` limit. `-mextern-sdata` is the default for all configurations.

If you compile a module *Mod* with `-mextern-sdata -G num -mgpopt`, and *Mod* references a variable *Var* that is no bigger than *num* bytes, you must make sure that *Var* is placed in a small data section. If *Var* is defined by another module, you must either compile that module with a high-enough `-G` setting or attach a `section` attribute to *Var*'s definition. If *Var* is common, you must link the application with a high-enough `-G` setting.

The easiest way of satisfying these restrictions is to compile and link every module with the same `-G` option. However, you may wish to build a library that supports several different small data limits. You can do this by compiling the library with the highest supported `-G` setting and additionally using `-mno-extern-sdata` to stop the library from making assumptions about externally-defined data.

`-mgpopt`
`-mno-gpopt`
Use (do not use) GP-relative accesses for symbols that are known to be in a small data section; see `-G`, `-mlocal-sdata` and `-mextern-sdata`. `-mgpopt` is the default for all configurations.

`-mno-gpopt` is useful for cases where the `$gp` register might not hold the value of `_gp`. For example, if the code is part of a library that might be used in a boot monitor, programs that call boot monitor routines pass an unknown value in `$gp`. (In such situations, the boot monitor itself is usually compiled with `-G0`.)

`-mno-gpopt` implies `-mno-local-sdata` and `-mno-extern-sdata`.

`-membedded-data`
`-mno-embedded-data`
Allocate variables to the read-only data section first if possible, then next in the small data section if possible, otherwise in data. This gives slightly slower code than the default, but reduces the amount of RAM required when executing, and thus may be preferred for some embedded systems.

`-muninit-const-in-rodata`
`-mno-uninit-const-in-rodata`
Put uninitialized `const` variables in the read-only data section. This option is only meaningful in conjunction with `-membedded-data`.

`-mcode-readable=setting`
Specify whether GCC may generate code that reads from executable sections. There are three possible settings:

`-mcode-readable=yes`
: Instructions may freely access executable sections. This is the default setting.

`-mcode-readable=pcrel`
: MIPS16 PC-relative load instructions can access executable sections, but other instructions must not do so. This option is useful on 4KSc and 4KSd processors when the code TLBs have the Read Inhibit bit set. It is also useful on processors that can be configured to have a dual instruction/data SRAM interface and that, like the M4K, automatically redirect PC-relative loads to the instruction RAM.

`-mcode-readable=no`
: Instructions must not access executable sections. This option can be useful on targets that are configured to have a dual instruction/data SRAM interface but that (unlike the M4K) do not automatically redirect PC-relative loads to the instruction RAM.

`-msplit-addresses`
`-mno-split-addresses`
: Enable (disable) use of the `%hi()` and `%lo()` assembler relocation operators. This option has been superseded by `-mexplicit-relocs` but is retained for backwards compatibility.

`-mexplicit-relocs=none`
`-mexplicit-relocs=base`
`-mexplicit-relocs=pcrel`
`-mexplicit-relocs`
`-mno-explicit-relocs`
: These options control whether explicit relocs (such as `%gp_rel`) are used. The default value depends on the version of GAS when GCC itself was built.

  The `base` explicit-relocs support was introduced into GAS in 2001. The `pcrel` explicit-relocs support was introduced into GAS in 2014, which supports `%pcrel_hi` and `%pcrel_lo`.

`-mcheck-zero-division`
`-mno-check-zero-division`
: Trap (do not trap) on integer division by zero.

  The default is `-mcheck-zero-division`.

`-mdivide-traps`
`-mdivide-breaks`
: MIPS systems check for division by zero by generating either a conditional trap or a break instruction. Using traps results in smaller code, but is only supported on MIPS II and later. Also, some versions of the Linux kernel have a bug that prevents trap from generating the proper signal (`SIGFPE`). Use `-mdivide-traps` to allow conditional traps on architectures that support them and `-mdivide-breaks` to force the use of breaks.

The default is usually `-mdivide-traps`, but this can be overridden at configure time using `--with-divide=breaks`. Divide-by-zero checks can be completely disabled using `-mno-check-zero-division`.

`-mload-store-pairs`
`-mno-load-store-pairs`
Enable (disable) an optimization that pairs consecutive load or store instructions to enable load/store bonding. This option is enabled by default but only takes effect when the selected architecture is known to support bonding.

`-mstrict-align`
`-mno-strict-align`
`-munaligned-access`
`-mno-unaligned-access`
Disable (enable) direct unaligned access for MIPS Release 6. MIPSr6 requires load/store unaligned-access support, by hardware or trap&emulate. So `-mstrict-align` may be needed by kernel. The options `-munaligned-access` and `-mno-unaligned-access` are obsoleted, and only for backward-compatible.

`-mmemcpy`
`-mno-memcpy`
Force (do not force) the use of `memcpy` for non-trivial block moves. The default is `-mno-memcpy`, which allows GCC to inline most constant-sized copies.

`-mlong-calls`
`-mno-long-calls`
Disable (do not disable) use of the `jal` instruction. Calling functions using `jal` is more efficient but requires the caller and callee to be in the same 256 megabyte segment.

This option has no effect on abicalls code. The default is `-mno-long-calls`.

`-mmad`
`-mno-mad` Enable (disable) use of the `mad`, `madu` and `mul` instructions, as provided by the R4650 ISA.

`-mimadd`
`-mno-imadd`
Enable (disable) use of the `madd` and `msub` integer instructions. The default is `-mimadd` on architectures that support `madd` and `msub` except for the 74k architecture where it was found to generate slower code.

`-mfused-madd`
`-mno-fused-madd`
Enable (disable) use of the floating-point multiply-accumulate instructions, when they are available. The default is `-mfused-madd`.

On the R8000 CPU when multiply-accumulate instructions are used, the intermediate product is calculated to infinite precision and is not subject to the FCSR Flush to Zero bit. This may be undesirable in some circumstances. On other processors the result is numerically identical to the equivalent computation using separate multiply, add, subtract and negate instructions.

`-nocpp` Tell the MIPS assembler to not run its preprocessor over user assembler files (with a '`.s`' suffix) when assembling them.

`-mfix-24k`
`-mno-fix-24k`
Work around the 24K E48 (lost data on stores during refill) errata. The workarounds are implemented by the assembler rather than by GCC.

`-mfix-r4000`
`-mno-fix-r4000`
Work around certain R4000 CPU errata:

- A double-word or a variable shift may give an incorrect result if executed immediately after starting an integer division.
- A double-word or a variable shift may give an incorrect result if executed while an integer multiplication is in progress.
- An integer division may give an incorrect result if started in a delay slot of a taken branch or a jump.

`-mfix-r4400`
`-mno-fix-r4400`
Work around certain R4400 CPU errata:

- A double-word or a variable shift may give an incorrect result if executed immediately after starting an integer division.

`-mfix-r10000`
`-mno-fix-r10000`
Work around certain R10000 errata:

- `ll`/`sc` sequences may not behave atomically on revisions prior to 3.0. They may deadlock on revisions 2.6 and earlier.

This option can only be used if the target architecture supports branch-likely instructions. `-mfix-r10000` is the default when `-march=r10000` is used; `-mno-fix-r10000` is the default otherwise.

`-mfix-r5900`
`-mno-fix-r5900`
Do not attempt to schedule the preceding instruction into the delay slot of a branch instruction placed at the end of a short loop of six instructions or fewer and always schedule a `nop` instruction there instead. The short loop bug under certain conditions causes loops to execute only once or twice, due to a hardware bug in the R5900 chip. The workaround is implemented by the assembler rather than by GCC.

`-mfix-rm7000`
`-mno-fix-rm7000`
Work around the RM7000 `dmult`/`dmultu` errata. The workarounds are implemented by the assembler rather than by GCC.

`-mfix-vr4120`
`-mno-fix-vr4120`
Work around certain VR4120 errata:

- `dmultu` does not always produce the correct result.
- `div` and `ddiv` do not always produce the correct result if one of the operands is negative.

The workarounds for the division errata rely on special functions in `libgcc.a`. At present, these functions are only provided by the `mips64vr*-elf` configurations.

Other VR4120 errata require a NOP to be inserted between certain pairs of instructions. These errata are handled by the assembler, not by GCC itself.

`-mfix-vr4130`
: Work around the VR4130 `mflo`/`mfhi` errata. The workarounds are implemented by the assembler rather than by GCC, although GCC avoids using `mflo` and `mfhi` if the VR4130 `macc`, `macchi`, `dmacc` and `dmacchi` instructions are available instead.

`-mfix-sb1`
`-mno-fix-sb1`
: Work around certain SB-1 CPU core errata. (This flag currently works around the SB-1 revision 2 "F1" and "F2" floating-point errata.)

`-mr10k-cache-barrier=`*`setting`*
: Specify whether GCC should insert cache barriers to avoid the side effects of speculation on R10K processors.

In common with many processors, the R10K tries to predict the outcome of a conditional branch and speculatively executes instructions from the "taken" branch. It later aborts these instructions if the predicted outcome is wrong. However, on the R10K, even aborted instructions can have side effects.

This problem only affects kernel stores and, depending on the system, kernel loads. As an example, a speculatively-executed store may load the target memory into cache and mark the cache line as dirty, even if the store itself is later aborted. If a DMA operation writes to the same area of memory before the "dirty" line is flushed, the cached data overwrites the DMA-ed data. See the R10K processor manual for a full description, including other potential problems.

One workaround is to insert cache barrier instructions before every memory access that might be speculatively executed and that might have side effects even if aborted. `-mr10k-cache-barrier=`*`setting`* controls GCC's implementation of this workaround. It assumes that aborted accesses to any byte in the following regions does not have side effects:

1. the memory occupied by the current function's stack frame;
2. the memory occupied by an incoming stack argument;
3. the memory occupied by an object with a link-time-constant address.

It is the kernel's responsibility to ensure that speculative accesses to these regions are indeed safe.

If the input program contains a function declaration such as:

```
void foo (void);
```

then the implementation of `foo` must allow `j foo` and `jal foo` to be executed speculatively. GCC honors this restriction for functions it compiles itself. It expects non-GCC functions (such as hand-written assembly code) to do the same.

The option has three forms:

`-mr10k-cache-barrier=load-store`
: Insert a cache barrier before a load or store that might be speculatively executed and that might have side effects even if aborted.

`-mr10k-cache-barrier=store`
: Insert a cache barrier before a store that might be speculatively executed and that might have side effects even if aborted.

`-mr10k-cache-barrier=none`
: Disable the insertion of cache barriers. This is the default setting.

`-mflush-func=`*`func`*
`-mno-flush-func`
: Specifies the function to call to flush the I and D caches, or to not call any such function. If called, the function must take the same arguments as the common `_flush_func`, that is, the address of the memory range for which the cache is being flushed, the size of the memory range, and the number 3 (to flush both caches). The default depends on the target GCC was configured for, but commonly is either `_flush_func` or `__cpu_flush`.

`-mbranch-cost=`*`num`*
: Set the cost of branches to roughly *num* “simple” instructions. This cost is only a heuristic and is not guaranteed to produce consistent results across releases. A zero cost redundantly selects the default, which is based on the `-mtune` setting.

`-mbranch-likely`
`-mno-branch-likely`
: Enable or disable use of Branch Likely instructions, regardless of the default for the selected architecture. By default, Branch Likely instructions may be generated if they are supported by the selected architecture. An exception is for the MIPS32 and MIPS64 architectures and processors that implement those architectures; for those, Branch Likely instructions are not be generated by default because the MIPS32 and MIPS64 architectures specifically deprecate their use.

`-mcompact-branches=never`
`-mcompact-branches=optimal`
`-mcompact-branches=always`
: These options control which form of branches will be generated. The default is `-mcompact-branches=optimal`.

  The `-mcompact-branches=never` option ensures that compact branch instructions will never be generated.

  The `-mcompact-branches=always` option ensures that a compact branch instruction will be generated if available for MIPS Release 6 onwards. If a compact branch instruction is not available (or pre-R6), a delay slot form of the branch will be used instead.

If it is used for MIPS16/microMIPS targets, it will be just ignored now. The behavior for MIPS16/microMIPS may change in future, since they do have some compact branch instructions.

The `-mcompact-branches=optimal` option will cause a delay slot branch to be used if one is available in the current ISA and the delay slot is successfully filled. If the delay slot is not filled, a compact branch will be chosen if one is available.

`-mfp-exceptions`
`-mno-fp-exceptions`

Specifies whether FP exceptions are enabled. This affects how FP instructions are scheduled for some processors. The default is that FP exceptions are enabled.

For instance, on the SB-1, if FP exceptions are disabled, and we are emitting 64-bit code, then we can use both FP pipes. Otherwise, we can only use one FP pipe.

`-mvr4130-align`
`-mno-vr4130-align`

The VR4130 pipeline is two-way superscalar, but can only issue two instructions together if the first one is 8-byte aligned. When this option is enabled, GCC aligns pairs of instructions that it thinks should execute in parallel.

This option only has an effect when optimizing for the VR4130. It normally makes code faster, but at the expense of making it bigger. It is enabled by default at optimization level `-O3`.

`-msynci`
`-mno-synci`

Enable (disable) generation of `synci` instructions on architectures that support it. The `synci` instructions (if enabled) are generated when `__builtin___clear_cache` is compiled.

This option defaults to `-mno-synci`, but the default can be overridden by configuring GCC with `--with-synci`.

When compiling code for single processor systems, it is generally safe to use `synci`. However, on many multi-core (SMP) systems, it does not invalidate the instruction caches on all cores and may lead to undefined behavior.

`-mrelax-pic-calls`
`-mno-relax-pic-calls`

Try to turn PIC calls that are normally dispatched via register `$25` into direct calls. This is only possible if the linker can resolve the destination at link time and if the destination is within range for a direct call.

`-mrelax-pic-calls` is the default if GCC was configured to use an assembler and a linker that support the `.reloc` assembly directive and `-mexplicit-relocs` is in effect. With `-mno-explicit-relocs`, this optimization can be performed by the assembler and the linker alone without help from the compiler.

`-mmcount-ra-address`
`-mno-mcount-ra-address`
: Emit (do not emit) code that allows `_mcount` to modify the calling function's return address. When enabled, this option extends the usual `_mcount` interface with a new *ra-address* parameter, which has type `intptr_t *` and is passed in register `$12`. `_mcount` can then modify the return address by doing both of the following:

- Returning the new address in register `$31`.
- Storing the new address in `*ra-address`, if *ra-address* is nonnull.

The default is `-mno-mcount-ra-address`.

`-mframe-header-opt`
`-mno-frame-header-opt`
: Enable (disable) frame header optimization in the o32 ABI. When using the o32 ABI, calling functions will allocate 16 bytes on the stack for the called function to write out register arguments. When enabled, this optimization will suppress the allocation of the frame header if it can be determined that it is unused.

This optimization is off by default at all optimization levels.

`-mlxc1-sxc1`
`-mno-lxc1-sxc1`
: When applicable, enable (disable) the generation of `lwxc1`, `swxc1`, `ldxc1`, `sdxc1` instructions. Enabled by default.

`-mmadd4`
`-mno-madd4`
: When applicable, enable (disable) the generation of 4-operand `madd.s`, `madd.d` and related instructions. Enabled by default.

3.20.30 MMIX Options

These options are defined for the MMIX:

`-mlibfuncs`
`-mno-libfuncs`
: Specify that intrinsic library functions are being compiled, passing all values in registers, no matter the size.

`-mepsilon`
`-mno-epsilon`
: Generate floating-point comparison instructions that compare with respect to the `rE` epsilon register.

`-mabi=mmixware`
`-mabi=gnu`
: Generate code that passes function parameters and return values that (in the called function) are seen as registers `$0` and up, as opposed to the GNU ABI which uses global registers `$231` and up.

`-mzero-extend`
`-mno-zero-extend`
: When reading data from memory in sizes shorter than 64 bits, use (do not use) zero-extending load instructions by default, rather than sign-extending ones.

`-mknuthdiv`
`-mno-knuthdiv`
: Make the result of a division yielding a remainder have the same sign as the divisor. With the default, `-mno-knuthdiv`, the sign of the remainder follows the sign of the dividend. Both methods are arithmetically valid, the latter being almost exclusively used.

`-mtoplevel-symbols`
`-mno-toplevel-symbols`
: Prepend (do not prepend) a '`:`' to all global symbols, so the assembly code can be used with the `PREFIX` assembly directive.

`-melf`
: Generate an executable in the ELF format, rather than the default '`mmo`' format used by the `mmix` simulator.

`-mbranch-predict`
`-mno-branch-predict`
: Use (do not use) the probable-branch instructions, when static branch prediction indicates a probable branch.

`-mbase-addresses`
`-mno-base-addresses`
: Generate (do not generate) code that uses *base addresses*. Using a base address automatically generates a request (handled by the assembler and the linker) for a constant to be set up in a global register. The register is used for one or more base address requests within the range 0 to 255 from the value held in the register. The generally leads to short and fast code, but the number of different data items that can be addressed is limited. This means that a program that uses lots of static data may require `-mno-base-addresses`.

`-msingle-exit`
`-mno-single-exit`
: Force (do not force) generated code to have a single exit point in each function.

3.20.31 MN10300 Options

These `-m` options are defined for Matsushita MN10300 architectures:

`-mmult-bug`
: Generate code to avoid bugs in the multiply instructions for the MN10300 processors. This is the default.

`-mno-mult-bug`
: Do not generate code to avoid bugs in the multiply instructions for the MN10300 processors.

`-mam33`
: Generate code using features specific to the AM33 processor.

`-mno-am33`
: Do not generate code using features specific to the AM33 processor. This is the default.

`-mam33-2` Generate code using features specific to the AM33/2.0 processor.

`-mam34` Generate code using features specific to the AM34 processor.

`-mtune=`*cpu-type*
: Use the timing characteristics of the indicated CPU type when scheduling instructions. This does not change the targeted processor type. The CPU type must be one of 'mn10300', 'am33', 'am33-2' or 'am34'.

`-mreturn-pointer-on-d0`
: When generating a function that returns a pointer, return the pointer in both a0 and d0. Otherwise, the pointer is returned only in a0, and attempts to call such functions without a prototype result in errors. Note that this option is on by default; use `-mno-return-pointer-on-d0` to disable it.

`-mno-crt0`
: Do not link in the C run-time initialization object file.

`-mrelax` Indicate to the linker that it should perform a relaxation optimization pass to shorten branches, calls and absolute memory addresses. This option only has an effect when used on the command line for the final link step.

This option makes symbolic debugging impossible.

`-mliw` Allow the compiler to generate *Long Instruction Word* instructions if the target is the 'AM33' or later. This is the default. This option defines the preprocessor macro `__LIW__`.

`-mno-liw` Do not allow the compiler to generate *Long Instruction Word* instructions. This option defines the preprocessor macro `__NO_LIW__`.

`-msetlb` Allow the compiler to generate the *SETLB* and *Lcc* instructions if the target is the 'AM33' or later. This is the default. This option defines the preprocessor macro `__SETLB__`.

`-mno-setlb`
: Do not allow the compiler to generate *SETLB* or *Lcc* instructions. This option defines the preprocessor macro `__NO_SETLB__`.

3.20.32 Moxie Options

`-meb` Generate big-endian code. This is the default for 'moxie-*-*' configurations.

`-mel` Generate little-endian code.

`-mmul.x` Generate mul.x and umul.x instructions. This is the default for 'moxiebox-*-*' configurations.

`-mno-crt0`
: Do not link in the C run-time initialization object file.

3.20.33 MSP430 Options

These options are defined for the MSP430:

`-masm-hex`
: Force assembly output to always use hex constants. Normally such constants are signed decimals, but this option is available for testsuite and/or aesthetic purposes.

`-mmcu=`
: Select the MCU to target. This is used to create a C preprocessor symbol based upon the MCU name, converted to upper case and pre- and post-fixed with '`__`'. This in turn is used by the `msp430.h` header file to select an MCU-specific supplementary header file.

  The option also sets the ISA to use. If the MCU name is one that is known to only support the 430 ISA then that is selected, otherwise the 430X ISA is selected. A generic MCU name of '`msp430`' can also be used to select the 430 ISA. Similarly the generic '`msp430x`' MCU name selects the 430X ISA.

  In addition an MCU-specific linker script is added to the linker command line. The script's name is the name of the MCU with `.ld` appended. Thus specifying `-mmcu=xxx` on the `gcc` command line defines the C preprocessor symbol `__XXX__` and cause the linker to search for a script called `xxx.ld`.

  The ISA and hardware multiply supported for the different MCUs is hard-coded into GCC. However, an external '`devices.csv`' file can be used to extend device support beyond those that have been hard-coded.

  GCC searches for the '`devices.csv`' file using the following methods in the given precedence order, where the first method takes precedence over the second which takes precedence over the third.

  Include path specified with `-I` and `-L`
  : '`devices.csv`' is searched for in each of the directories specified by include paths and linker library search paths.

  Path specified by the environment variable '`MSP430_GCC_INCLUDE_DIR`'
  : Define the value of the global environment variable '`MSP430_GCC_INCLUDE_DIR`' to the full path to the directory containing devices.csv, and GCC will search this directory for devices.csv. If devices.csv is found, this directory is also registered as an include path and linker library path. Header files and linker scripts in this directory can therefore be used without manually specifying `-I` and `-L` on the command line.

  The '`msp430-elf{,bare}/include/devices`' directory
  : Finally, GCC examines '`msp430-elf{,bare}/include/devices`' from the toolchain root directory. This directory does not exist in a default installation, but if the user has created it and copied '`devices.csv`' there, then the MCU data is read. As above, this directory is also registered as an include path and linker library path.

  If none of the above search methods find '`devices.csv`', then the hard-coded MCU data is used.

-mwarn-mcu
-mno-warn-mcu
: This option enables or disables warnings about conflicts between the MCU name specified by the -mmcu option and the ISA set by the -mcpu option and/or the hardware multiply support set by the -mhwmult option. It also toggles warnings about unrecognized MCU names. This option is on by default.

-mcpu=
: Specifies the ISA to use. Accepted values are 'msp430', 'msp430x' and 'msp430xv2'. This option is deprecated. The -mmcu= option should be used to select the ISA.

-msim
: Link to the simulator runtime libraries and linker script. Overrides any scripts that would be selected by the -mmcu= option.

-mlarge
: Use large-model addressing (20-bit pointers, 20-bit size_t).

-msmall
: Use small-model addressing (16-bit pointers, 16-bit size_t).

-mrelax
: This option is passed to the assembler and linker, and allows the linker to perform certain optimizations that cannot be done until the final link.

mhwmult=
: Describes the type of hardware multiply supported by the target. Accepted values are 'none' for no hardware multiply, '16bit' for the original 16-bit-only multiply supported by early MCUs. '32bit' for the 16/32-bit multiply supported by later MCUs and 'f5series' for the 16/32-bit multiply supported by F5-series MCUs. A value of 'auto' can also be given. This tells GCC to deduce the hardware multiply support based upon the MCU name provided by the -mmcu option. If no -mmcu option is specified or if the MCU name is not recognized then no hardware multiply support is assumed. auto is the default setting.

  Hardware multiplies are normally performed by calling a library routine. This saves space in the generated code. When compiling at -O3 or higher however the hardware multiplier is invoked inline. This makes for bigger, but faster code.

  The hardware multiply routines disable interrupts whilst running and restore the previous interrupt state when they finish. This makes them safe to use inside interrupt handlers as well as in normal code.

-minrt
: Enable the use of a minimum runtime environment - no static initializers or constructors. This is intended for memory-constrained devices. The compiler includes special symbols in some objects that tell the linker and runtime which code fragments are required.

-mtiny-printf
: Enable reduced code size printf and puts library functions. The 'tiny' implementations of these functions are not reentrant, so must be used with caution in multi-threaded applications.

  Support for streams has been removed and the string to be printed will always be sent to stdout via the write syscall. The string is not buffered before it is sent to write.

This option requires Newlib Nano IO, so GCC must be configured with '--enable-newlib-nano-formatted-io'.

-mmax-inline-shift=
This option takes an integer between 0 and 64 inclusive, and sets the maximum number of inline shift instructions which should be emitted to perform a shift operation by a constant amount. When this value needs to be exceeded, an mspabi helper function is used instead. The default value is 4.

This only affects cases where a shift by multiple positions cannot be completed with a single instruction (e.g. all shifts >1 on the 430 ISA).

Shifts of a 32-bit value are at least twice as costly, so the value passed for this option is divided by 2 and the resulting value used instead.

-mcode-region=
-mdata-region=
These options tell the compiler where to place functions and data that do not have one of the lower, upper, either or section attributes. Possible values are lower, upper, either or any. The first three behave like the corresponding attribute. The fourth possible value - any - is the default. It leaves placement entirely up to the linker script and how it assigns the standard sections (.text, .data, etc) to the memory regions.

-msilicon-errata=
This option passes on a request to assembler to enable the fixes for the named silicon errata.

-msilicon-errata-warn=
This option passes on a request to the assembler to enable warning messages when a silicon errata might need to be applied.

-mwarn-devices-csv
-mno-warn-devices-csv
Warn if 'devices.csv' is not found or there are problem parsing it (default: on).

3.20.34 NDS32 Options

These options are defined for NDS32 implementations:

-mbig-endian
Generate code in big-endian mode.

-mlittle-endian
Generate code in little-endian mode.

-mreduced-regs
Use reduced-set registers for register allocation.

-mfull-regs
Use full-set registers for register allocation.

-mcmov Generate conditional move instructions.

`-mno-cmov`
: Do not generate conditional move instructions.

`-mext-perf`
: Generate performance extension instructions.

`-mno-ext-perf`
: Do not generate performance extension instructions.

`-mext-perf2`
: Generate performance extension 2 instructions.

`-mno-ext-perf2`
: Do not generate performance extension 2 instructions.

`-mext-string`
: Generate string extension instructions.

`-mno-ext-string`
: Do not generate string extension instructions.

`-mv3push` Generate v3 push25/pop25 instructions.

`-mno-v3push`
: Do not generate v3 push25/pop25 instructions.

`-m16-bit` Generate 16-bit instructions.

`-mno-16-bit`
: Do not generate 16-bit instructions.

`-misr-vector-size=`*num*
: Specify the size of each interrupt vector, which must be 4 or 16.

`-mcache-block-size=`*num*
: Specify the size of each cache block, which must be a power of 2 between 4 and 512.

`-march=`*arch*
: Specify the name of the target architecture.

`-mcmodel=`*code-model*
: Set the code model to one of

  ‘`small`’ All the data and read-only data segments must be within 512KB addressing space. The text segment must be within 16MB addressing space.

  ‘`medium`’ The data segment must be within 512KB while the read-only data segment can be within 4GB addressing space. The text segment should be still within 16MB addressing space.

  ‘`large`’ All the text and data segments can be within 4GB addressing space.

`-mctor-dtor`
: Enable constructor/destructor feature.

`-mrelax` Guide linker to relax instructions.

3.20.35 Nvidia PTX Options

These options are defined for Nvidia PTX:

`-m64` Ignored, but preserved for backward compatibility. Only 64-bit ABI is supported.

`-march=`*`architecture-string`*
: Generate code for the specified PTX ISA target architecture. Valid architecture strings are 'sm_30', 'sm_35', 'sm_37', 'sm_52', 'sm_53', 'sm_61', 'sm_70', 'sm_75', 'sm_80', and 'sm_89'. The default depends on how the compiler has been configured, see `--with-arch`.

  This option sets the value of the preprocessor macro `__PTX_SM__`; for instance, for 'sm_35', it has the value '350'.

`-misa=`*`architecture-string`*
: Alias of `-march=`.

`-march-map=`*`architecture-string`*
: Select the closest available `-march=` value that is not more capable. For instance, for `-march-map=sm_50` select `-march=sm_37`, and for `-march-map=sm_53` select `-march=sm_53`.

`-mptx=`*`version-string`*
: Generate code for the specified PTX ISA version. Valid version strings are '3.1', '4.1', '4.2', '5.0', '6.0', '6.3', '7.0', '7.3', and '7.8'. The default PTX ISA version is the one that added support for the selected PTX ISA target architecture, see `-march=`, but at least '6.3', or '7.3' for `-march=sm_52` and higher.

  This option sets the values of the preprocessor macros `__PTX_ISA_VERSION_MAJOR__` and `__PTX_ISA_VERSION_MINOR__`; for instance, for '3.1' the macros have the values '3' and '1', respectively.

`-mmainkernel`
: Link in code for a __main kernel. This is for stand-alone instead of offloading execution.

`-moptimize`
: Apply partitioned execution optimizations. This is the default when any level of optimization is selected.

`-msoft-stack`
`-mno-soft-stack`
: For `-mno-soft-stack` (the default, unless `-mgomp` has been specified), use PTX "native" stacks, that is, generate code that uses `.local` memory or PTX `alloca` directly for stack storage. Unless `-mptx=7.3` or higher and `-march=sm_52` or higher are active, variable-length arrays and dynamically allocating memory on the stack with `alloca` are not supported.

  For `-msoft-stack` (implied by `-mgomp`), generate code that does not use `.local` memory or PTX `alloca` directly for stack storage. Instead, a per-warp stack pointer is maintained explicitly. This enables variable-length stack allocation (with variable-length arrays or `alloca`), and when global memory is used for underlying storage, makes it possible to access automatic variables from other threads, or with atomic instructions. This code generation variant is used for OpenMP offloading, but the option is exposed on its own for the purpose of testing the compiler; to generate code suitable for linking into programs using OpenMP offloading, use option `-mgomp`.

`-muniform-simt`
: Switch to code generation variant that allows to execute all threads in each warp, while maintaining memory state and side effects as if only one thread in each warp was active outside of OpenMP SIMD regions. All atomic operations and calls to runtime (malloc, free, vprintf) are conditionally executed (iff current lane index equals the master lane index), and the register being assigned is copied via a shuffle instruction from the master lane. Outside of SIMD regions lane 0 is the master; inside, each thread sees itself as the master. Shared memory array `int __nvptx_uni[]` stores all-zeros or all-ones bitmasks for each warp, indicating current mode (0 outside of SIMD regions). Each thread can bitwise-and the bitmask at position `tid.y` with current lane index to compute the master lane index.

`-mgomp`
: Generate code for use in OpenMP offloading: enables `-msoft-stack` and `-muniform-simt` options, and selects corresponding multilib variant.

3.20.36 OpenRISC Options

These options are defined for OpenRISC:

`-mboard=name`
: Configure a board specific runtime. This will be passed to the linker for newlib board library linking. The default is `or1ksim`.

`-mnewlib`
: This option is ignored; it is for compatibility purposes only. This used to select linker and preprocessor options for use with newlib.

`-msoft-div`
`-mhard-div`
: Select software or hardware divide (`l.div`, `l.divu`) instructions. This default is hardware divide.

`-msoft-mul`
`-mhard-mul`
: Select software or hardware multiply (`l.mul`, `l.muli`) instructions. This default is hardware multiply.

`-msoft-float`
`-mhard-float`
: Select software or hardware for floating point operations. The default is software.

`-mdouble-float`
: When `-mhard-float` is selected, enables generation of double-precision floating point instructions. By default functions from `libgcc` are used to perform double-precision floating point operations.

`-munordered-float`
: When `-mhard-float` is selected, enables generation of unordered floating point compare and set flag (`lf.sfun*`) instructions. By default functions from `libgcc` are used to perform unordered floating point compare and set flag operations.

`-mcmov`
: Enable generation of conditional move (`l.cmov`) instructions. By default the equivalent will be generated using set and branch.

`-mror`
: Enable generation of rotate right (`l.ror`) instructions. By default functions from `libgcc` are used to perform rotate right operations.

`-mrori`
: Enable generation of rotate right with immediate (`l.rori`) instructions. By default functions from `libgcc` are used to perform rotate right with immediate operations.

`-msext`
: Enable generation of sign extension (`l.ext*`) instructions. By default memory loads are used to perform sign extension.

`-msfimm`
: Enable generation of compare and set flag with immediate (`l.sf*i`) instructions. By default extra instructions will be generated to store the immediate to a register first.

`-mshftimm`
: Enable generation of shift with immediate (`l.srai`, `l.srli`, `l.slli`) instructions. By default extra instructions will be generated to store the immediate to a register first.

`-mcmodel=small`
: Generate OpenRISC code for the small model: The GOT is limited to 64k and function call jumps are limited to 64M offsets. This is the default model.

`-mcmodel=large`
: Generate OpenRISC code for the large model: The GOT may grow up to 4G in size and function call jumps can target the full 4G address space.

3.20.37 PDP-11 Options

These options are defined for the PDP-11:

`-mfpu`
: Use hardware FPP floating point. This is the default. (FIS floating point on the PDP-11/40 is not supported.) Implies -m45.

`-msoft-float`
: Do not use hardware floating point.

`-mac0`
: Return floating-point results in ac0 (fr0 in Unix assembler syntax).

`-mno-ac0`
: Return floating-point results in memory. This is the default.

`-m40`
: Generate code for a PDP-11/40. Implies -msoft-float -mno-split.

`-m45`
: Generate code for a PDP-11/45. This is the default.

`-m10`
: Generate code for a PDP-11/10. Implies -msoft-float -mno-split.

`-mint16`
`-mno-int32`
: Use 16-bit `int`. This is the default.

`-mint32`
`-mno-int16`
Use 32-bit `int`.

`-msplit` Target has split instruction and data space. Implies -m45.

`-munix-asm`
Use Unix assembler syntax.

`-mdec-asm`
Use DEC assembler syntax.

`-mgnu-asm`
Use GNU assembler syntax. This is the default.

`-mlra` Use the new LRA register allocator. By default, the old "reload" allocator is used.

3.20.38 PowerPC Options

These are listed under See Section 3.20.42 [RS/6000 and PowerPC Options], page 493.

3.20.39 PRU Options

These command-line options are defined for PRU target:

`-minrt` Link with a minimum runtime environment. This can significantly reduce the size of the final ELF binary, but some standard C runtime features are removed.

This option disables support for static initializers and constructors. Beware that the compiler could still generate code with static initializers and constructors. It is up to the programmer to ensure that the source program will not use those features.

The minimal startup code would not pass `argc` and `argv` arguments to `main`, so the latter must be declared as `int main (void)`. This is already the norm for most firmware projects.

`-mmcu=`*mcu*
Specify the PRU hardware variant to use. A correspondingly named spec file would be loaded, passing the memory region sizes to the linker and defining hardware-specific C macros.

Newlib provides only the `sim` spec, intended for running regression tests using a simulator. Specs for real hardware can be obtained by installing the GnuPruMcu (`https://github.com/dinuxbg/gnuprumcu/`) package.

`-mno-relax`
Make GCC pass the `--no-relax` command-line option to the linker instead of the `--relax` option.

`-mloop` Allow (or do not allow) GCC to use the LOOP instruction.

`-mmul` Allow (or do not allow) GCC to use the PRU multiplier unit.

`-mfillzero`
Allow (or do not allow) GCC to use the FILL and ZERO instructions.

`-mabi=`*`variant`*
: Specify the ABI variant to output code for. `-mabi=ti` selects the unmodified TI ABI while `-mabi=gnu` selects a GNU variant that copes more naturally with certain GCC assumptions. These are the differences:

  '`Function Pointer Size`'
  : TI ABI specifies that function (code) pointers are 16-bit, whereas GNU supports only 32-bit data and code pointers.

  '`Optional Return Value Pointer`'
  : Function return values larger than 64 bits are passed by using a hidden pointer as the first argument of the function. TI ABI, though, mandates that the pointer can be NULL in case the caller is not using the returned value. GNU always passes and expects a valid return value pointer.

  '`Size Of Struct Containing Bit-fields`'
  : TI ABI mandates that struct size is determined by the bit-field type, if it contains any. Whereas GNU allocates the smallest amount of bytes which would fit the bit-field.

    For example, TI ABI reserves 4 bytes for this struct, whereas GNU reserves a single byte:

    ```
    struct S { int i:1; };
    ```

  '`Access Size For Volatile Bit-fields`'
  : TI ABI mandates that volatile bit-fields are accessed using their type. In contrast, GNU ABI uses the smallest integer type fitting the bit-field.

    For example, TI ABI requires a single load of 4 bytes for the following bit-field. Whereas GNU generates a load of 1 byte:

    ```
    struct S { volatile int i:1; };
    ```

  The current `-mabi=ti` implementation simply raises a compile error when any of the above code constructs is detected. As a consequence the standard C library cannot be built and it is omitted when linking with `-mabi=ti`.

  Relaxation is a GNU feature and for safety reasons is disabled when using `-mabi=ti`. The TI toolchain does not emit relocations for QBBx instructions, so the GNU linker cannot adjust them when shortening adjacent LDI32 pseudo instructions.

3.20.40 RISC-V Options

These command-line options are defined for RISC-V targets:

`-mbranch-cost=`*`n`*
: Set the cost of branches to roughly *n* instructions.

`-mplt`
`-mno-plt`
: When generating PIC code, do or don't allow the use of PLTs. Ignored for non-PIC. The default is `-mplt`.

`-mabi=ABI-string`

Specify integer and floating-point calling convention. *ABI-string* contains two parts: the size of integer types and the registers used for floating-point types. For example '`-march=rv64ifd -mabi=lp64d`' means that '`long`' and pointers are 64-bit (implicitly defining '`int`' to be 32-bit), and that floating-point values up to 64 bits wide are passed in F registers. Contrast this with '`-march=rv64ifd -mabi=lp64f`', which still allows the compiler to generate code that uses the F and D extensions but only allows floating-point values up to 32 bits long to be passed in registers; or '`-march=rv64ifd -mabi=lp64`', in which no floating-point arguments will be passed in registers.

The default for this argument is system dependent, users who want a specific calling convention should specify one explicitly. The valid calling conventions are: '`ilp32`', '`ilp32f`', '`ilp32d`', '`lp64`', '`lp64f`', and '`lp64d`'. Some calling conventions are impossible to implement on some ISAs: for example, '`-march=rv32if -mabi=ilp32d`' is invalid because the ABI requires 64-bit values be passed in F registers, but F registers are only 32 bits wide. There are also the '`ilp32e`' ABI that can only be used with the '`rv32e`' architecture and the '`lp64e`' ABI that can only be used with the '`rv64e`'. Those ABIs are not well specified at present, and are subject to change.

`-mfdiv`
`-mno-fdiv`

Do or don't use hardware floating-point divide and square root instructions. This requires the F or D extensions for floating-point registers. The default is to use them if the specified architecture has these instructions.

`-mfence-tso`
`-mno-fence-tso`

Do or don't use the '`fence.tso`' instruction, which is unimplemented on some processors (including those from T-Head). If the '`fence.tso`' instruction is not available then a stronger fence is used instead.

`-mdiv`
`-mno-div`

Do or don't use hardware instructions for integer division. This requires the M extension. The default is to use them if the specified architecture has these instructions.

`-misa-spec=ISA-spec-string`

Specify the version of the RISC-V Unprivileged (formerly User-Level) ISA specification to produce code conforming to. The possibilities for *ISA-spec-string* are:

`2.2` Produce code conforming to version 2.2.

`20190608` Produce code conforming to version 20190608.

`20191213` Produce code conforming to version 20191213.

The default is `-misa-spec=20191213` unless GCC has been configured with `--with-isa-spec=` specifying a different default version.

`-march=ISA-string|Profiles|Profile_ISA-string|help|unset`

Generate code for given RISC-V ISA or Profiles or a combination of them (e.g. 'rv64im' 'rvi20u64' 'rvi20u64_zbb'). ISA strings and Profiles must be lower-case. Examples include 'rv64i', 'rv32g', 'rv32e', 'rv32imaf', 'rva22u64' and 'rva23u64'. To combine Profiles and optional RISC-V ISA extention, the profile should start at the beginning of the option, then use underline connect ISA-string (e.g. 'rvi20u64_zca_zcb' 'rva23u64_zacas'). Additionally, a special value `help` (`-march=help`) is accepted to list all supported extensions.

'-march=unset' causes the compiler to ignore any '-march=...' options that appear earlier on the command line, behaving as if the option was never passed. This is useful for ensuring that the architecture is taken from the '-mcpu' option, and it will result in an error if no '-mcpu' option is given when '-march=unset' is used.

The syntax of the ISA string is defined as follows:

`The string must start with 'rv32' or 'rv64', followed by`
'i', 'e', or 'g', referred to as the base ISA.

`The subsequent part of the string is a list of extension names. Extension`
names can be categorized as multi-letter (e.g. 'zba') and single-letter (e.g. 'v'). Single-letter extensions can appear consecutively, but multi-letter extensions must be separated by underscores.

`An underscore can appear anywhere after the base ISA. It has no specific`
effect but is used to improve readability and can act as a separator.

`Extension names may include an optional version number, following the`
syntax '<major>p<minor>' or '<major>', (e.g. 'm2p1' or 'm2').

Supported extension are listed below:

Extension Name	**Supported Version**	**Description**
g	-	General-purpose computing base extension, 'g' will expand to 'i', 'm', 'a', 'f', 'd', 'zicsr' and 'zifencei'.
e	2.0	Reduced base integer extension
i	2.0 2.1	Base integer extension
m	2.0	Integer multiplication and division extension
a	2.0 2.1	Atomic extension
f	2.0 2.2	Single-precision floating-point extension

d	2.0 2.2	Double-precision floating-point extension
c	2.0	Compressed extension
b	1.0	b extension
v	1.0	Vector extension
h	1.0	Hypervisor extension
zic64b	1.0	Cache block size isf 64 bytes
zicbom	1.0	Cache-block management extension
zicbop	1.0	Cache-block prefetch extension
zicboz	1.0	Cache-block zero extension
ziccamoa	1.0	Main memory supports all atomics in A
ziccif	1.0	Main memory supports instruction fetch with atomicity requirement
zicclsm	1.0	Main memory supports misaligned loads/stores
ziccrse	1.0	Main memory supports forward progress on LR/SC sequences
zicfilp	1.0	zicfilp extension
zicfiss	1.0	zicfiss extension
zicntr	2.0	Standard extension for base counters and timers
zicond	1.0	Integer conditional operations extension
zicsr	2.0	Control and status register access extension
zifencei	2.0	Instruction-fetch fence extension
zihintntl	1.0	Non-temporal locality hints extension
zihintpause	2.0	Pause hint extension

zihpm	2.0	Standard extension for hardware performance counters
zimop	1.0	zimop extension
zilsd	1.0	Load/Store pair instructions extension
zmmul	1.0	Integer multiplication extension
za128rs	1.0	Reservation set size of 128 bytes
za64rs	1.0	Reservation set size of 64 bytes
zaamo	1.0	zaamo extension
zabha	1.0	zabha extension
zacas	1.0	zacas extension
zalrsc	1.0	zalrsc extension
zawrs	1.0	Wait-on-reservation-set extension
zama16b	1.0	Zama16b extension, Misaligned loads, stores, and AMOs to main memory regions that do not cross a naturally aligned 16-byte boundary are atomic.
zfa	1.0	Additional floating-point extension
zfbfmin	1.0	zfbfmin extension
zfh	1.0	Half-precision floating-point extension
zfhmin	1.0	Minimal half-precision floating-point extension
zfinx	1.0	Single-precision floating-point in integer registers extension
zdinx	1.0	Double-precision floating-point in integer registers extension
zca	1.0	Integer compressed instruction extension
zcb	1.0	Simple compressed instruction extension
zcd	1.0	Compressed double-precision floating point loads and stores extension

zce	1.0	Compressed instruction extensions for embedded processors
zcf	1.0	Compressed single-precision floating point loads and stores extension
zcmop	1.0	zcmop extension
zcmp	1.0	Compressed push pop extension
zcmt	1.0	Table jump instruction extension
zclsd	1.0	Compressed load/store pair instructions extension
zba	1.0	Address calculation extension
zbb	1.0	Basic bit manipulation extension
zbc	1.0	Carry-less multiplication extension
zbkb	1.0	Cryptography bit-manipulation extension
zbkc	1.0	Cryptography carry-less multiply extension
zbkx	1.0	Cryptography crossbar permutation extension
zbs	1.0	Single-bit operation extension
zk	1.0	Standard scalar cryptography extension
zkn	1.0	NIST algorithm suite extension
zknd	1.0	AES Decryption extension
zkne	1.0	AES Encryption extension
zknh	1.0	Hash function extension
zkr	1.0	Entropy source extension
zks	1.0	ShangMi algorithm suite extension
zksed	1.0	SM4 block cipher extension
zksh	1.0	SM3 hash function extension

zkt	1.0	Data independent execution latency extension
ztso	1.0	Total store ordering extension
zvbb	1.0	Vector basic bit-manipulation extension
zvbc	1.0	Vector carryless multiplication extension
zve32f	1.0	Vector extensions for embedded processors
zve32x	1.0	Vector extensions for embedded processors
zve64d	1.0	Vector extensions for embedded processors
zve64f	1.0	Vector extensions for embedded processors
zve64x	1.0	Vector extensions for embedded processors
zvfbfmin	1.0	Vector BF16 converts extension
zvfbfwma	1.0	zvfbfwma extension
zvfh	1.0	Vector half-precision floating-point extension
zvfhmin	1.0	Vector minimal half-precision floating-point extension
zvkb	1.0	Vector cryptography bit-manipulation extension
zvkg	1.0	Vector GCM/GMAC extension
zvkn	1.0	Vector NIST Algorithm Suite extension, '`zvkn`' will expand to
zvknc	1.0	Vector NIST Algorithm Suite with carryless multiply extension, '`zvknc`'
zvkned	1.0	Vector AES block cipher extension
zvkng	1.0	Vector NIST Algorithm Suite with GCM extension, '`zvkng`' will expand
zvknha	1.0	Vector SHA-2 secure hash extension
zvknhb	1.0	Vector SHA-2 secure hash extension

zvks	1.0	Vector ShangMi algorithm suite extension, ‘`zvks`’ will expand
zvksc	1.0	Vector ShangMi algorithm suite with carryless multiplication extension,
zvksed	1.0	Vector SM4 Block Cipher extension
zvksg	1.0	Vector ShangMi algorithm suite with GCM extension, ‘`zvksg`’ will expand
zvksh	1.0	Vector SM3 Secure Hash extension
zvkt	1.0	Vector data independent execution latency extension
zvl1024b	1.0	Minimum vector length standard extensions
zvl128b	1.0	Minimum vector length standard extensions
zvl16384b	1.0	zvl16384b extension
zvl2048b	1.0	Minimum vector length standard extensions
zvl256b	1.0	Minimum vector length standard extensions
zvl32768b	1.0	zvl32768b extension
zvl32b	1.0	Minimum vector length standard extensions
zvl4096b	1.0	Minimum vector length standard extensions
zvl512b	1.0	Minimum vector length standard extensions
zvl64b	1.0	Minimum vector length standard extensions
zvl65536b	1.0	zvl65536b extension
zvl8192b	1.0	zvl8192b extension
zhinx	1.0	Half-precision floating-point in integer registers extension
zhinxmin	1.0	Minimal half-precision floating-point in integer registers extension
sdtrig	1.0	sdtrig extension

sha	1.0	The augmented hypervisor extension
shcounterenw	1.0	Support writeable enables for any supported counter
shgatpa	1.0	SvNNx4 mode supported for all modes supported by satp
shlcofideleg	1.0	Delegating LCOFI interrupts to VS-mode
shtvala	1.0	The htval register provides all needed values
shvstvala	1.0	The vstval register provides all needed values
shvstvecd	1.0	The vstvec register supports Direct mode
shvsatpa	1.0	The vsatp register supports all modes supported by satp
smaia	1.0	Advanced interrupt architecture extension
smcntrpmf	1.0	Cycle and instret privilege mode filtering
smcsrind	1.0	Machine-Level Indirect CSR Access
smepmp	1.0	PMP Enhancements for memory access and execution prevention on Machine mode
smmpm	1.0	smmpm extension
smnpm	1.0	smnpm extension
smrnmi	1.0	Resumable non-maskable interrupts
smstateen	1.0	State enable extension
smdbltrp	1.0	Double Trap Extensions
ssaia	1.0	Advanced interrupt architecture extension for supervisor-mode
ssccptr	1.0	Main memory supports page table reads
sscofpmf	1.0	Count overflow & filtering extension
sscounterenw	1.0	Support writeable enables for any supported counter

sscsrind	1.0	Supervisor-Level Indirect CSR Access
ssnpm	1.0	ssnpm extension
sspm	1.0	sspm extension
ssstateen	1.0	State-enable extension for supervisor-mode
sstc	1.0	Supervisor-mode timer interrupts extension
sstvala	1.0	Stval provides all needed values
sstvecd	1.0	Stvec supports Direct mode
ssstrict	1.0	ssstrict extension
ssdbltrp	1.0	Double Trap Extensions
ssu64xl	1.0	UXLEN=64 must be supported
supm	1.0	supm extension
svinval	1.0	Fine-grained address-translation cache invalidation extension
svnapot	1.0	NAPOT translation contiguity extension
svpbmt	1.0	Page-based memory types extension
svvptc	1.0	svvptc extension
svadu	1.0	Hardware Updating of A/D Bits extension
svade	1.0	Cause exception when hardware updating of A/D bits is disabled
svbare	1.0	Satp mode bare is supported
xcvalu	1.0	Core-V miscellaneous ALU extension
xcvbi	1.0	xcvbi extension
xcvelw	1.0	Core-V event load word extension
xcvmac	1.0	Core-V multiply-accumulate extension

xcvsimd	1.0	xcvsimd extension
xsfcease	1.0	xsfcease extension
xsfvcp	1.0	xsfvcp extension
xsfvfnrclipxfqf	1.0	xsfvfnrclipxfqf extension
xsfvqmaccdod	1.0	xsfvqmaccdod extension
xsfvqmaccqoq	1.0	xsfvqmaccqoq extension
xtheadba	1.0	T-head address calculation extension
xtheadbb	1.0	T-head basic bit-manipulation extension
xtheadbs	1.0	T-head single-bit instructions extension
xtheadcmo	1.0	T-head cache management operations extension
xtheadcondmov	1.0	T-head conditional move extension
xtheadfmemidx	1.0	T-head indexed memory operations for floating-point registers extension
xtheadfmv	1.0	T-head double floating-point high-bit data transmission extension
xtheadint	1.0	T-head acceleration interruption extension
xtheadmac	1.0	T-head multiply-accumulate extension
xtheadmemidx	1.0	T-head indexed memory operation extension
xtheadmempair	1.0	T-head two-GPR memory operation extension
xtheadsync	1.0	T-head multi-core synchronization extension
xtheadvector	1.0	xtheadvector extension
xventanacondops	1.0	Ventana integer conditional operations extension
xmipscmov	1.0	Mips conditional move extension

xmipscbop	1.0	Mips Prefetch extension
xandesperf	5.0	Andes performace extension
xandesbfhcvt	5.0	Andes bfloat16 conversion extension
xandesvbfhcvt	5.0	Andes vector bfloat16 conversion extension
xandesvsintload	5.0	Andes vector INT4 load extension
xandesvpackfph	5.0	Andes vector packed FP16 extension
xandesvdot	5.0	Andes vector dot product extension
xsmtvdot	1.0	SpacemiT vector dot product extension

When `-march=` is not specified, use the setting from `-mcpu`.

If both `-march` and `-mcpu=` are not specified, the default for this argument is system dependent, users who want a specific architecture extensions should specify one explicitly.

When the RISC-V specifications define an extension as depending on other extensions, GCC will implicitly add the dependent extensions to the enabled extension set if they weren't added explicitly.

'`Core Name`'

`-mcpu=`*`processor-string`*

Use architecture of and optimize the output for the given processor, specified by particular CPU name. Permissible values for this option are:

'`sifive-e20`',

'`sifive-e21`',

'`sifive-e24`',

'`sifive-e31`',

'`sifive-e34`',

'`sifive-e76`',

'`sifive-s21`',

'`sifive-s51`',

'`sifive-s54`',

'`sifive-s76`',

'`sifive-u54`',

'`sifive-u74`',

'`sifive-x280`',

'`sifive-p450`',

'`sifive-p670`',

'thead-c906',
'xt-c908',
'xt-c908v',
'xt-c910',
'xt-c910v2',
'xt-c920',
'xt-c920v2',
'tt-ascalon-d8',
'xiangshan-nanhu',
'xiangshan-kunminghu',
'mips-p8700',
'andes-n22',
'andes-n25',
'andes-a25',
'andes-nx25',
'andes-ax25',
'andes-a27',
'andes-ax27',
'andes-n225',
'andes-d23',
'andes-n45',
'andes-nx45',
'andes-a45',
'andes-ax45',
'spacemit-x60'.

Note that `-mcpu` does not override `-march` or `-mtune`.

'Tune Name'

`-mtune=`*processor-string*

Optimize the output for the given processor, specified by microarchitecture or particular CPU name. Permissible values for this option are:

'generic',
'rocket',
'sifive-3-series',
'sifive-5-series',
'sifive-7-series',
'sifive-p400-series',
'sifive-p600-series',
'tt-ascalon-d8',
'thead-c906',

'xt-c908',
'xt-c908v',
'xt-c910',
'xt-c910v2',
'xt-c920',
'xt-c920v2',
'xiangshan-nanhu',
'xiangshan-kunminghu',
'spacemit-x60',
'generic-ooo',
'size',
'mips-p8700',
'andes-25-series',
'andes-23-series',
'andes-45-series',
and all valid options for `-mcpu=`.

When `-mtune=` is not specified, use the setting from `-mcpu`, the default is 'generic' if both are not specified.

The 'size' choice is not intended for use by end-users. This is used when `-Os` is specified. It overrides the instruction cost info provided by `-mtune=`, but does not override the pipeline info. This helps reduce code size while still giving good performance.

`-mpreferred-stack-boundary=`*num*
: Attempt to keep the stack boundary aligned to a 2 raised to *num* byte boundary. If `-mpreferred-stack-boundary` is not specified, the default is 4 (16 bytes or 128-bits).

  Warning: If you use this switch, then you must build all modules with the same value, including any libraries. This includes the system libraries and startup modules.

`-msmall-data-limit=`*n*
: Put global and static data smaller than *n* bytes into a special section (on some targets).

`-msave-restore`
`-mno-save-restore`
: Do or don't use smaller but slower prologue and epilogue code that uses library function calls. The default is to use fast inline prologues and epilogues.

`-mmovcc`
`-mno-movcc`
: Do or don't produce branchless conditional-move code sequences even with targets that do not have specific instructions for conditional operations. If enabled, sequences of ALU operations are produced using base integer ISA instructions where profitable.

-minline-atomics
-mno-inline-atomics

Do or don't use smaller but slower subword atomic emulation code that uses libatomic function calls. The default is to use fast inline subword atomics that do not require libatomic.

-minline-strlen
-mno-inline-strlen

Do or do not attempt to inline strlen calls if possible. Inlining will only be done if the string is properly aligned and instructions for accelerated processing are available. The default is to not inline strlen calls.

-minline-strcmp
-mno-inline-strcmp

Do or do not attempt to inline strcmp calls if possible. Inlining will only be done if the strings are properly aligned and instructions for accelerated processing are available. The default is to not inline strcmp calls.

The **--param** `riscv-strcmp-inline-limit=n` parameter controls the maximum number of bytes compared by the inlined code. The default value is 64.

-minline-strncmp
-mno-inline-strncmp

Do or do not attempt to inline strncmp calls if possible. Inlining will only be done if the strings are properly aligned and instructions for accelerated processing are available. The default is to not inline strncmp calls.

The **--param** `riscv-strcmp-inline-limit=n` parameter controls the maximum number of bytes compared by the inlined code. The default value is 64.

-mshorten-memrefs
-mno-shorten-memrefs

Do or do not attempt to make more use of compressed load/store instructions by replacing a load/store of 'base register + large offset' with a new load/store of 'new base + small offset'. If the new base gets stored in a compressed register, then the new load/store can be compressed. Currently targets 32-bit integer load/stores only.

-mstrict-align
-mno-strict-align

Do not or do generate unaligned memory accesses. The default is set depending on whether the processor we are optimizing for supports fast unaligned access or not.

-mscalar-strict-align
-mno-scalar-strict-align

Do not or do generate unaligned memory accesses. The default is set depending on whether the processor we are optimizing for supports fast unaligned access or not. This is an alias for **-mstrict-align**.

`-mvector-strict-align`
`-mno-vector-strict-align`
: Do not or do generate unaligned vector memory accesses. The default is set to off unless the processor we are optimizing for explicitly supports element-misaligned vector memory access.

`-mcmodel=medlow`
: Generate code for the medium-low code model. The program and its statically defined symbols must lie within a single 2 GiB address range and must lie between absolute addresses −2 GiB and +2 GiB. Programs can be statically or dynamically linked. This is the default code model unless GCC has been configured with `--with-cmodel=` specifying a different default code model.

`-mcmodel=medany`
: Generate code for the medium-any code model. The program and its statically defined symbols must be within any single 2 GiB address range. Programs can be statically or dynamically linked.

  The code generated by the medium-any code model is position-independent, but is not guaranteed to function correctly when linked into position-independent executables or libraries.

`-mcmodel=large`
: Generate code for a large code model, which has no restrictions on size or placement of symbols.

`-mexplicit-relocs`
`-mno-exlicit-relocs`
: Use or do not use assembler relocation operators when dealing with symbolic addresses. The alternative is to use assembler macros instead, which may limit optimization.

`-mrelax`
`-mno-relax`
: Take advantage of linker relaxations to reduce the number of instructions required to materialize symbol addresses. The default is to take advantage of linker relaxations.

`-mriscv-attribute`
`-mno-riscv-attribute`
: Emit (do not emit) RISC-V attribute to record extra information into ELF objects. This feature requires at least binutils 2.32.

`-mcsr-check`
`-mno-csr-check`
: Enables or disables the CSR checking.

`-malign-data=`*`type`*
: Control how GCC aligns variables and constants of array, structure, or union types. Supported values for *type* are '`xlen`' which uses x register width as the alignment value, and '`natural`' which uses natural alignment. '`xlen`' is the default.

`-mbig-endian`
: Generate big-endian code. This is the default when GCC is configured for a 'riscv64be-*-*' or 'riscv32be-*-*' target.

`-mlittle-endian`
: Generate little-endian code. This is the default when GCC is configured for a 'riscv64-*-*' or 'riscv32-*-*' but not a 'riscv64be-*-*' or 'riscv32be-*-*' target.

`-mstack-protector-guard=guard`
`-mstack-protector-guard-reg=reg`
`-mstack-protector-guard-offset=offset`
: Generate stack protection code using canary at *guard*. Supported locations are 'global' for a global canary or 'tls' for per-thread canary in the TLS block.

  With the latter choice the options `-mstack-protector-guard-reg=reg` and `-mstack-protector-guard-offset=offset` furthermore specify which register to use as base register for reading the canary, and from what offset from that base register. There is no default register or offset as this is entirely for use within the Linux kernel.

`-mtls-dialect=desc`
: Use TLS descriptors as the thread-local storage mechanism for dynamic accesses of TLS variables.

`-mtls-dialect=trad`
: Use traditional TLS as the thread-local storage mechanism for dynamic accesses of TLS variables. This is the default.

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`-msim`
: Links in additional target libraries to support operation within a simulator.

`-mmul=none`
`-mmul=g10`
`-mmul=g13`
`-mmul=g14`
`-mmul=rl78`
: Specifies the type of hardware multiplication and division support to be used. The simplest is `none`, which uses software for both multiplication and division. This is the default. The `g13` value is for the hardware multiply/divide peripheral found on the RL78/G13 (S2 core) targets. The `g14` value selects the use of the multiplication and division instructions supported by the RL78/G14 (S3 core) parts. The value `rl78` is an alias for `g14` and the value `mg10` is an alias for `none`.

  In addition a C preprocessor macro is defined, based upon the setting of this option. Possible values are: `__RL78_MUL_NONE__`, `__RL78_MUL_G13__` or `__RL78_MUL_G14__`.

`-mcpu=g10`
`-mcpu=g13`
`-mcpu=g14`
`-mcpu=rl78`

Specifies the RL78 core to target. The default is the G14 core, also known as an S3 core or just RL78. The G13 or S2 core does not have multiply or divide instructions, instead it uses a hardware peripheral for these operations. The G10 or S1 core does not have register banks, so it uses a different calling convention.

If this option is set it also selects the type of hardware multiply support to use, unless this is overridden by an explicit `-mmul=none` option on the command line. Thus specifying `-mcpu=g13` enables the use of the G13 hardware multiply peripheral and specifying `-mcpu=g10` disables the use of hardware multiplications altogether.

Note, although the RL78/G14 core is the default target, specifying `-mcpu=g14` or `-mcpu=rl78` on the command line does change the behavior of the toolchain since it also enables G14 hardware multiply support. If these options are not specified on the command line then software multiplication routines will be used even though the code targets the RL78 core. This is for backwards compatibility with older toolchains which did not have hardware multiply and divide support.

In addition a C preprocessor macro is defined, based upon the setting of this option. Possible values are: `__RL78_G10__`, `__RL78_G13__` or `__RL78_G14__`.

`-mg10`
`-mg13`
`-mg14`
`-mrl78`

These are aliases for the corresponding `-mcpu=` option. They are provided for backwards compatibility.

`-mallregs`

Allow the compiler to use all of the available registers. By default registers `r24..r31` are reserved for use in interrupt handlers. With this option enabled these registers can be used in ordinary functions as well.

`-m64bit-doubles`
`-m32bit-doubles`

Make the `double` data type be 64 bits (`-m64bit-doubles`) or 32 bits (`-m32bit-doubles`) in size. The default is `-m32bit-doubles`.

`-msave-mduc-in-interrupts`
`-mno-save-mduc-in-interrupts`

Specifies that interrupt handler functions should preserve the MDUC registers. This is only necessary if normal code might use the MDUC registers, for example because it performs multiplication and division operations. The default is to ignore the MDUC registers as this makes the interrupt handlers faster. The target option -mg13 needs to be passed for this to work as this feature is only available on the G13 target (S2 core). The MDUC registers will only be saved if the interrupt handler performs a multiplication or division operation or it calls another function.

3.20.42 IBM RS/6000 and PowerPC Options

These '-m' options are defined for the IBM RS/6000 and PowerPC:

-mpowerpc-gpopt
-mno-powerpc-gpopt
-mpowerpc-gfxopt
-mno-powerpc-gfxopt
-mpowerpc64
-mno-powerpc64
-mmfcrf
-mno-mfcrf
-mpopcntb
-mno-popcntb
-mpopcntd
-mno-popcntd
-mfprnd
-mno-fprnd
-mcmpb
-mno-cmpb
-mhard-dfp
-mno-hard-dfp

You use these options to specify which instructions are available on the processor you are using. The default value of these options is determined when configuring GCC. Specifying the -mcpu=*cpu_type* overrides the specification of these options. We recommend you use the -mcpu=*cpu_type* option rather than the options listed above.

Specifying -mpowerpc-gpopt allows GCC to use the optional PowerPC architecture instructions in the General Purpose group, including floating-point square root. Specifying -mpowerpc-gfxopt allows GCC to use the optional PowerPC architecture instructions in the Graphics group, including floating-point select.

The -mmfcrf option allows GCC to generate the move from condition register field instruction implemented on the POWER4 processor and other processors that support the PowerPC V2.01 architecture. The -mpopcntb option allows GCC to generate the popcount and double-precision FP reciprocal estimate instruction implemented on the POWER5 processor and other processors that support the PowerPC V2.02 architecture. The -mpopcntd option allows GCC to generate the popcount instruction implemented on the POWER7 processor and other processors that support the PowerPC V2.06 architecture. The -mfprnd option allows GCC to generate the FP round to integer instructions implemented on the POWER5+ processor and other processors that support the PowerPC V2.03 architecture. The -mcmpb option allows GCC to generate the compare bytes instruction implemented on the POWER6 processor and other processors that support the PowerPC V2.05 architecture. The -mhard-dfp option allows GCC to generate the decimal floating-point instructions implemented on some POWER processors.

The -mpowerpc64 option allows GCC to generate the additional 64-bit instructions that are found in the full PowerPC64 architecture and to treat GPRs as 64-bit, doubleword quantities. GCC defaults to -mno-powerpc64.

-mcpu=*cpu_type*

Set architecture type, register usage, and instruction scheduling parameters for machine type *cpu_type*. Supported values for *cpu_type* are '401', '403', '405', '405fp', '440', '440fp', '464', '464fp', '476', '476fp', '505', '601', '602', '603', '603e', '604', '604e', '620', '630', '740', '7400', '7450', '750', '801', '821', '823', '860', '970', '8540', 'a2', 'e300c2', 'e300c3', 'e500mc', 'e500mc64', 'e5500', 'e6500', 'ec603e', 'G3', 'G4', 'G5', 'titan', 'power3', 'power4', 'power5', 'power5+', 'power6', 'power6x', 'power7', 'power8', 'power9', 'power10', 'power11', 'powerpc', 'powerpc64', 'powerpc64le', 'rs64', and 'native'.

-mcpu=powerpc, -mcpu=powerpc64, and -mcpu=powerpc64le specify pure 32-bit PowerPC (either endian), 64-bit big endian PowerPC and 64-bit little endian PowerPC architecture machine types, with an appropriate, generic processor model assumed for scheduling purposes.

Specifying 'native' as cpu type detects and selects the architecture option that corresponds to the host processor of the system performing the compilation. -mcpu=native has no effect if GCC does not recognize the processor.

The other options specify a specific processor. Code generated under those options runs best on that processor, and may not run at all on others.

The -mcpu options automatically enable or disable the following options:

```
-maltivec  -mfprnd  -mhard-float  -mmfcrf  -mmultiple
-mpopcntb  -mpopcntd  -mpowerpc64
-mpowerpc-gpopt  -mpowerpc-gfxopt
-mmulhw  -mdlmzb  -mmfpgpr  -mvsx
-mcrypto  -mhtm  -mpower8-fusion
-mquad-memory  -mquad-memory-atomic  -mfloat128
-mfloat128-hardware -mprefixed -mpcrel -mmma
-mrop-protect
```

The particular options set for any particular CPU varies between compiler versions, depending on what setting seems to produce optimal code for that CPU; it doesn't necessarily reflect the actual hardware's capabilities. If you wish to set an individual option to a particular value, you may specify it after the -mcpu option, like -mcpu=970 -mno-altivec.

On AIX, the -maltivec and -mpowerpc64 options are not enabled or disabled by the -mcpu option at present because AIX does not have full support for these options. You may still enable or disable them individually if you're sure it'll work in your environment.

-mtune=*cpu_type*

Set the instruction scheduling parameters for machine type *cpu_type*, but do not set the architecture type or register usage, as -mcpu=*cpu_type* does. The same values for *cpu_type* are used for -mtune as for -mcpu. If both are specified, the code generated uses the architecture and registers set by -mcpu, but the scheduling parameters set by -mtune.

`-mcmodel=small`
: Generate PowerPC64 code for the small model: The TOC is limited to 64k.

`-mcmodel=medium`
: Generate PowerPC64 code for the medium model: The TOC and other static data may be up to a total of 4G in size. This is the default for 64-bit Linux.

`-mcmodel=large`
: Generate PowerPC64 code for the large model: The TOC may be up to 4G in size. Other data and code is only limited by the 64-bit address space.

`-maltivec`
`-mno-altivec`
: Generate code that uses (does not use) AltiVec instructions, and also enable the use of built-in functions that allow more direct access to the AltiVec instruction set. You may also need to set `-mabi=altivec` to adjust the current ABI with AltiVec ABI enhancements.

  When `-maltivec` is used, the element order for AltiVec intrinsics such as `vec_splat`, `vec_extract`, and `vec_insert` match array element order corresponding to the endianness of the target. That is, element zero identifies the leftmost element in a vector register when targeting a big-endian platform, and identifies the rightmost element in a vector register when targeting a little-endian platform.

`-mvrsave`
`-mno-vrsave`
: Generate VRSAVE instructions when generating AltiVec code.

`-msecure-plt`
: Generate code that allows `ld` and `ld.so` to build executables and shared libraries with non-executable `.plt` and `.got` sections. This is a PowerPC 32-bit SYSV ABI option.

`-mbss-plt`
: Generate code that uses a BSS `.plt` section that `ld.so` fills in, and requires `.plt` and `.got` sections that are both writable and executable. This is a PowerPC 32-bit SYSV ABI option.

`-msplit-patch-nops`
: When adding NOPs for a patchable area via the `-fpatchable-function-entry` option emit the "before" NOPs in front of the global entry point and the "after" NOPs after the local entry point. This makes the sequence of NOPs not consecutive when a global entry point is generated. Without this option the NOPs are emitted directly before and after the local entry point, making them consecutive but moving global and local entry point further apart. If only a single entry point is generated this option has no effect.

`-misel`
`-mno-isel`
: This switch enables or disables the generation of ISEL instructions.

-mvsx
-mno-vsx Generate code that uses (does not use) vector/scalar (VSX) instructions, and also enable the use of built-in functions that allow more direct access to the VSX instruction set.

-mcrypto
-mno-crypto
Enable the use (disable) of the built-in functions that allow direct access to the cryptographic instructions that were added in version 2.07 of the PowerPC ISA.

-mhtm
-mno-htm Enable (disable) the use of the built-in functions that allow direct access to the Hardware Transactional Memory (HTM) instructions that were added in version 2.07 of the PowerPC ISA.

-mpower8-fusion
-mno-power8-fusion
Generate code that keeps (does not keeps) some integer operations adjacent so that the instructions can be fused together on power8 and later processors.

-mquad-memory
-mno-quad-memory
Generate code that uses (does not use) the non-atomic quad word memory instructions. The `-mquad-memory` option requires use of 64-bit mode.

-mquad-memory-atomic
-mno-quad-memory-atomic
Generate code that uses (does not use) the atomic quad word memory instructions. The `-mquad-memory-atomic` option requires use of 64-bit mode.

-mfloat128
-mno-float128
Enable/disable the *__float128* keyword for IEEE 128-bit floating point and use either software emulation for IEEE 128-bit floating point or hardware instructions.

The VSX instruction set (`-mvsx`) must be enabled to use the IEEE 128-bit floating point support. The IEEE 128-bit floating point is only supported on Linux.

The default for `-mfloat128` is enabled on PowerPC Linux systems using the VSX instruction set, and disabled on other systems.

If you use the ISA 3.0 instruction set (`-mcpu=power9`) on a 64-bit system, the IEEE 128-bit floating point support will also enable the generation of ISA 3.0 IEEE 128-bit floating point instructions. Otherwise, if you do not specify to generate ISA 3.0 instructions or you are targeting a 32-bit big endian system, IEEE 128-bit floating point will be done with software emulation.

-mfloat128-hardware
-mno-float128-hardware
Enable/disable using ISA 3.0 hardware instructions to support the *__float128* data type.

The default for `-mfloat128-hardware` is enabled on PowerPC Linux systems using the ISA 3.0 instruction set, and disabled on other systems.

`-m32`
`-m64`
: Generate code for 32-bit or 64-bit environments of Darwin and SVR4 targets (including GNU/Linux). The 32-bit environment sets int, long and pointer to 32 bits and generates code that runs on any PowerPC variant. The 64-bit environment sets int to 32 bits and long and pointer to 64 bits, and generates code for PowerPC64, as for `-mpowerpc64`.

`-mfull-toc`
`-mno-fp-in-toc`
`-mno-sum-in-toc`
`-mminimal-toc`
: Modify generation of the TOC (Table Of Contents), which is created for every executable file. The `-mfull-toc` option is selected by default. In that case, GCC allocates at least one TOC entry for each unique non-automatic variable reference in your program. GCC also places floating-point constants in the TOC. However, only 16,384 entries are available in the TOC.

If you receive a linker error message that saying you have overflowed the available TOC space, you can reduce the amount of TOC space used with the `-mno-fp-in-toc` and `-mno-sum-in-toc` options. `-mno-fp-in-toc` prevents GCC from putting floating-point constants in the TOC and `-mno-sum-in-toc` forces GCC to generate code to calculate the sum of an address and a constant at run time instead of putting that sum into the TOC. You may specify one or both of these options. Each causes GCC to produce very slightly slower and larger code at the expense of conserving TOC space.

If you still run out of space in the TOC even when you specify both of these options, specify `-mminimal-toc` instead. This option causes GCC to make only one TOC entry for every file. When you specify this option, GCC produces code that is slower and larger but which uses extremely little TOC space. You may wish to use this option only on files that contain less frequently-executed code.

`-maix64`
`-maix32`
: Enable 64-bit AIX ABI and calling convention: 64-bit pointers, 64-bit `long` type, and the infrastructure needed to support them. Specifying `-maix64` implies `-mpowerpc64`, while `-maix32` disables the 64-bit ABI and implies `-mno-powerpc64`. GCC defaults to `-maix32`.

`-mxl-compat`
`-mno-xl-compat`
: Produce code that conforms more closely to IBM XL compiler semantics when using AIX-compatible ABI. Pass floating-point arguments to prototyped functions beyond the register save area (RSA) on the stack in addition to argument FPRs. Do not assume that most significant double in 128-bit long double value is properly rounded when comparing values and converting to double. Use XL symbol names for long double support routines.

The AIX calling convention was extended but not initially documented to handle an obscure K&R C case of calling a function that takes the address of its arguments with fewer arguments than declared. IBM XL compilers access floating-point arguments that do not fit in the RSA from the stack when a subroutine is compiled without optimization. Because always storing floating-point arguments on the stack is inefficient and rarely needed, this option is not enabled by default and only is necessary when calling subroutines compiled by IBM XL compilers without optimization.

`-mpe` Support *IBM RS/6000 SP Parallel Environment* (PE). Link an application written to use message passing with special startup code to enable the application to run. The system must have PE installed in the standard location (`/usr/lpp/ppe.poe/`), or the `specs` file must be overridden with the `-specs=` option to specify the appropriate directory location. The Parallel Environment does not support threads, so the `-mpe` option and the `-pthread` option are incompatible.

`-malign-natural`
`-malign-power`
On AIX, 32-bit Darwin, and 64-bit PowerPC GNU/Linux, the option `-malign-natural` overrides the ABI-defined alignment of larger types, such as floating-point doubles, on their natural size-based boundary. The option `-malign-power` instructs GCC to follow the ABI-specified alignment rules. GCC defaults to the standard alignment defined in the ABI.

On 64-bit Darwin, natural alignment is the default, and `-malign-power` is not supported.

`-msoft-float`
`-mhard-float`
Generate code that does not use (uses) the floating-point register set. Software floating-point emulation is provided if you use the `-msoft-float` option, and pass the option to GCC when linking.

`-mmultiple`
`-mno-multiple`
Generate code that uses (does not use) the load multiple word instructions and the store multiple word instructions. These instructions are generated by default on POWER systems, and not generated on PowerPC systems. Do not use `-mmultiple` on little-endian PowerPC systems, since those instructions do not work when the processor is in little-endian mode. The exceptions are PPC740 and PPC750 which permit these instructions in little-endian mode.

`-mupdate`
`-mno-update`
Generate code that uses (does not use) the load or store instructions that update the base register to the address of the calculated memory location. These instructions are generated by default. If you use `-mno-update`, there is a small window between the time that the stack pointer is updated and the address of the previous frame is stored, which means code that walks the stack frame across interrupts or signals may get corrupted data.

`-mavoid-indexed-addresses`
`-mno-avoid-indexed-addresses`
: Generate code that tries to avoid (not avoid) the use of indexed load or store instructions. These instructions can incur a performance penalty on Power6 processors in certain situations, such as when stepping through large arrays that cross a 16M boundary. This option is enabled by default when targeting Power6 and disabled otherwise.

`-mfused-madd`
`-mno-fused-madd`
: Generate code that uses (does not use) the floating-point multiply and accumulate instructions. These instructions are generated by default if hardware floating point is used. The machine-dependent `-mfused-madd` option is now mapped to the machine-independent `-ffp-contract=fast` option, and `-mno-fused-madd` is mapped to `-ffp-contract=off`.

`-mmulhw`
`-mno-mulhw`
: Generate code that uses (does not use) the half-word multiply and multiply-accumulate instructions on the IBM 405, 440, 464 and 476 processors. These instructions are generated by default when targeting those processors.

`-mdlmzb`
`-mno-dlmzb`
: Generate code that uses (does not use) the string-search '`dlmzb`' instruction on the IBM 405, 440, 464 and 476 processors. This instruction is generated by default when targeting those processors.

`-mno-bit-align`
`-mbit-align`
: On System V.4 and embedded PowerPC systems do not (do) force structures and unions that contain bit-fields to be aligned to the base type of the bit-field.

  For example, by default a structure containing nothing but 8 `unsigned` bit-fields of length 1 is aligned to a 4-byte boundary and has a size of 4 bytes. By using `-mno-bit-align`, the structure is aligned to a 1-byte boundary and is 1 byte in size.

`-mno-strict-align`
`-mstrict-align`
: On System V.4 and embedded PowerPC systems do not (do) assume that unaligned memory references are handled by the system.

`-mrelocatable`
`-mno-relocatable`
: Generate code that allows (does not allow) a static executable to be relocated to a different address at run time. A simple embedded PowerPC system loader should relocate the entire contents of `.got2` and 4-byte locations listed in the `.fixup` section, a table of 32-bit addresses generated by this option. For this to work, all objects linked together must be compiled with `-mrelocatable` or `-mrelocatable-lib`. `-mrelocatable` code aligns the stack to an 8-byte boundary.

`-mrelocatable-lib`
`-mno-relocatable-lib`
: Like `-mrelocatable`, `-mrelocatable-lib` generates a `.fixup` section to allow static executables to be relocated at run time, but `-mrelocatable-lib` does not use the smaller stack alignment of `-mrelocatable`. Objects compiled with `-mrelocatable-lib` may be linked with objects compiled with any combination of the `-mrelocatable` options.

`-mno-toc`
`-mtoc`
: On System V.4 and embedded PowerPC systems do not (do) assume that register 2 contains a pointer to a global area pointing to the addresses used in the program.

`-mlittle`
`-mlittle-endian`
: On System V.4 and embedded PowerPC systems compile code for the processor in little-endian mode. The `-mlittle-endian` option is the same as `-mlittle`.

`-mbig`
`-mbig-endian`
: On System V.4 and embedded PowerPC systems compile code for the processor in big-endian mode. The `-mbig-endian` option is the same as `-mbig`.

`-mdynamic-no-pic`
: On Darwin / macOS systems, compile code so that it is not relocatable, but that its external references are relocatable. The resulting code is suitable for applications, but not shared libraries.

`-msingle-pic-base`
: Treat the register used for PIC addressing as read-only, rather than loading it in the prologue for each function. The runtime system is responsible for initializing this register with an appropriate value before execution begins.

`-mprioritize-restricted-insns=`*`priority`*
: This option controls the priority that is assigned to dispatch-slot restricted instructions during the second scheduling pass. The argument *priority* takes the value '`0`', '`1`', or '`2`' to assign no, highest, or second-highest (respectively) priority to dispatch-slot restricted instructions.

`-msched-costly-dep=`*`dependence_type`*
: This option controls which dependences are considered costly by the target during instruction scheduling. The argument *dependence_type* takes one of the following values:

  '`no`' No dependence is costly.

  '`all`' All dependences are costly.

  '`true_store_to_load`'
  : A true dependence from store to load is costly.

  '`store_to_load`'
  : Any dependence from store to load is costly.

number Any dependence for which the latency is greater than or equal to *number* is costly.

`-minsert-sched-nops=scheme`
: This option controls which NOP insertion scheme is used during the second scheduling pass. The argument *scheme* takes one of the following values:

  ‘`no`’ Don’t insert NOPs.

  ‘`pad`’ Pad with NOPs any dispatch group that has vacant issue slots, according to the scheduler’s grouping.

  ‘`regroup_exact`’
  : Insert NOPs to force costly dependent insns into separate groups. Insert exactly as many NOPs as needed to force an insn to a new group, according to the estimated processor grouping.

  number Insert NOPs to force costly dependent insns into separate groups. Insert *number* NOPs to force an insn to a new group.

`-mcall-sysv`
: On System V.4 and embedded PowerPC systems compile code using calling conventions that adhere to the March 1995 draft of the System V Application Binary Interface, PowerPC processor supplement. This is the default unless you configured GCC using ‘`powerpc-*-eabiaix`’.

`-mcall-sysv-eabi`
`-mcall-eabi`
: Specify both `-mcall-sysv` and `-meabi` options.

`-mcall-sysv-noeabi`
: Specify both `-mcall-sysv` and `-mno-eabi` options.

`-mcall-aixdesc`
: On System V.4 and embedded PowerPC systems compile code for the AIX operating system.

`-mcall-linux`
: On System V.4 and embedded PowerPC systems compile code for the Linux-based GNU system.

`-mcall-freebsd`
: On System V.4 and embedded PowerPC systems compile code for the FreeBSD operating system.

`-mcall-netbsd`
: On System V.4 and embedded PowerPC systems compile code for the NetBSD operating system.

`-mcall-openbsd`
: On System V.4 and embedded PowerPC systems compile code for the OpenBSD operating system.

`-mtraceback=traceback_type`
: Select the type of traceback table. Valid values for *traceback_type* are ‘`full`’, ‘`part`’, and ‘`no`’.

`-maix-struct-return`
: Return all structures in memory (as specified by the AIX ABI).

`-msvr4-struct-return`
: Return structures smaller than 8 bytes in registers (as specified by the SVR4 ABI).

`-mabi=`*abi-type*
: Extend the current ABI with a particular extension, or remove such extension. Valid values are: '`altivec`', '`no-altivec`', '`ibmlongdouble`', '`ieeelongdouble`', '`elfv1`', '`elfv2`', and for AIX: '`vec-extabi`', '`vec-default`'.

`-mabi=ibmlongdouble`
: Change the current ABI to use IBM extended-precision long double. This is not likely to work if your system defaults to using IEEE extended-precision long double. If you change the long double type from IEEE extended-precision, the compiler issues a warning unless you use the `-Wno-psabi` option (see Section 3.9 [Warning Options], page 100). Requires `-mlong-double-128` to be enabled.

`-mabi=ieeelongdouble`
: Change the current ABI to use IEEE extended-precision long double. This is not likely to work if your system defaults to using IBM extended-precision long double. If you change the long double type from IBM extended-precision, the compiler issues a warning unless you use the `-Wno-psabi` option (see Section 3.9 [Warning Options], page 100). Requires `-mlong-double-128` to be enabled.

`-mabi=elfv1`
: Change the current ABI to use the ELFv1 ABI. This is the default ABI for big-endian PowerPC 64-bit Linux. Overriding the default ABI requires special system support and is likely to fail in spectacular ways.

`-mabi=elfv2`
: Change the current ABI to use the ELFv2 ABI. This is the default ABI for little-endian PowerPC 64-bit Linux. Overriding the default ABI requires special system support and is likely to fail in spectacular ways.

`-mgnu-attribute`
`-mno-gnu-attribute`
: Emit .gnu_attribute assembly directives to set tag/value pairs in a .gnu.attributes section that specify ABI variations in function parameters or return values.

`-mprototype`
`-mno-prototype`
: On System V.4 and embedded PowerPC systems assume that all calls to variable argument functions are properly prototyped. Otherwise, the compiler must insert an instruction before every non-prototyped call to set or clear bit 6 of the condition code register (`CR`) to indicate whether floating-point values are passed in the floating-point registers in case the function takes variable arguments. With `-mprototype`, only calls to prototyped variable argument functions set or clear the bit.

-msim On embedded PowerPC systems, assume that the startup module is called sim-crt0.o and that the standard C libraries are libsim.a and libc.a. This is the default for 'powerpc-*-eabisim' configurations.

-mmvme On embedded PowerPC systems, assume that the startup module is called crt0.o and the standard C libraries are libmvme.a and libc.a.

-mads On embedded PowerPC systems, assume that the startup module is called crt0.o and the standard C libraries are libads.a and libc.a.

-myellowknife
On embedded PowerPC systems, assume that the startup module is called crt0.o and the standard C libraries are libyk.a and libc.a.

-mvxworks
On System V.4 and embedded PowerPC systems, specify that you are compiling for a VxWorks system.

-memb On embedded PowerPC systems, set the PPC_EMB bit in the ELF flags header to indicate that 'eabi' extended relocations are used.

-meabi
-mno-eabi
On System V.4 and embedded PowerPC systems do (do not) adhere to the Embedded Applications Binary Interface (EABI), which is a set of modifications to the System V.4 specifications. Selecting -meabi means that the stack is aligned to an 8-byte boundary, a function __eabi is called from main to set up the EABI environment, and the -msdata option can use both r2 and r13 to point to two separate small data areas. Selecting -mno-eabi means that the stack is aligned to a 16-byte boundary, no EABI initialization function is called from main, and the -msdata option only uses r13 to point to a single small data area. The -meabi option is on by default if you configured GCC using one of the 'powerpc*-*-eabi*' options.

-msdata=eabi
On System V.4 and embedded PowerPC systems, put small initialized const global and static data in the .sdata2 section, which is pointed to by register r2. Put small initialized non-const global and static data in the .sdata section, which is pointed to by register r13. Put small uninitialized global and static data in the .sbss section, which is adjacent to the .sdata section. The -msdata=eabi option is incompatible with the -mrelocatable option. The -msdata=eabi option also sets the -memb option.

-msdata=sysv
On System V.4 and embedded PowerPC systems, put small global and static data in the .sdata section, which is pointed to by register r13. Put small uninitialized global and static data in the .sbss section, which is adjacent to the .sdata section. The -msdata=sysv option is incompatible with the -mrelocatable option.

`-msdata=default`
`-msdata` On System V.4 and embedded PowerPC systems, if `-meabi` is used, compile code the same as `-msdata=eabi`, otherwise compile code the same as `-msdata=sysv`.

`-msdata=data`
On System V.4 and embedded PowerPC systems, put small global data in the `.sdata` section. Put small uninitialized global data in the `.sbss` section. Do not use register `r13` to address small data however. This is the default behavior unless other `-msdata` options are used.

`-msdata=none`
`-mno-sdata`
On embedded PowerPC systems, put all initialized global and static data in the `.data` section, and all uninitialized data in the `.bss` section.

`-mreadonly-in-sdata`
Put read-only objects in the `.sdata` section as well. This is the default.

`-mblock-move-inline-limit=`*num*
Inline all block moves (such as calls to `memcpy` or structure copies) less than or equal to *num* bytes. The minimum value for *num* is 32 bytes on 32-bit targets and 64 bytes on 64-bit targets. The default value is target-specific.

`-mblock-compare-inline-limit=`*num*
Generate non-looping inline code for all block compares (such as calls to `memcmp` or structure compares) less than or equal to *num* bytes. If *num* is 0, all inline expansion (non-loop and loop) of block compare is disabled. The default value is target-specific.

`-mblock-compare-inline-loop-limit=`*num*
Generate an inline expansion using loop code for all block compares that are less than or equal to *num* bytes, but greater than the limit for non-loop inline block compare expansion. If the block length is not constant, at most *num* bytes will be compared before `memcmp` is called to compare the remainder of the block. The default value is target-specific.

`-mstring-compare-inline-limit=`*num*
Compare at most *num* string bytes with inline code. If the difference or end of string is not found at the end of the inline compare a call to `strcmp` or `strncmp` will take care of the rest of the comparison. The default is 64 bytes.

`-G` *num* On embedded PowerPC systems, put global and static items less than or equal to *num* bytes into the small data or BSS sections instead of the normal data or BSS section. By default, *num* is 8. The `-G` *num* switch is also passed to the linker. All modules should be compiled with the same `-G` *num* value.

`-mregnames`
`-mno-regnames`
On System V.4 and embedded PowerPC systems do (do not) emit register names in the assembly language output using symbolic forms.

`-mlongcall`
`-mno-longcall`

By default assume that all calls are far away so that a longer and more expensive calling sequence is required. This is required for calls farther than 32 megabytes (33,554,432 bytes) from the current location. A short call is generated if the compiler knows the call cannot be that far away. This setting can be overridden by the `shortcall` function attribute, or by `#pragma longcall(0)`.

Some linkers are capable of detecting out-of-range calls and generating glue code on the fly. On these systems, long calls are unnecessary and generate slower code. As of this writing, the AIX linker can do this, as can the GNU linker for PowerPC/64. It is planned to add this feature to the GNU linker for 32-bit PowerPC systems as well.

On PowerPC64 ELFv2 and 32-bit PowerPC systems with newer GNU linkers, GCC can generate long calls using an inline PLT call sequence (see `-mpltseq`). PowerPC with `-mbss-plt` and PowerPC64 ELFv1 (big-endian) do not support inline PLT calls.

On Darwin/PPC systems, `#pragma longcall` generates `jbsr callee, L42`, plus a *branch island* (glue code). The two target addresses represent the callee and the branch island. The Darwin/PPC linker prefers the first address and generates a `bl callee` if the PPC `bl` instruction reaches the callee directly; otherwise, the linker generates `bl L42` to call the branch island. The branch island is appended to the body of the calling function; it computes the full 32-bit address of the callee and jumps to it.

On Mach-O (Darwin) systems, this option directs the compiler emit to the glue for every direct call, and the Darwin linker decides whether to use or discard it.

In the future, GCC may ignore all longcall specifications when the linker is known to generate glue.

`-mpltseq`
`-mno-pltseq`

Implement (do not implement) -fno-plt and long calls using an inline PLT call sequence that supports lazy linking and long calls to functions in dlopen'd shared libraries. Inline PLT calls are only supported on PowerPC64 ELFv2 and 32-bit PowerPC systems with newer GNU linkers, and are enabled by default if the support is detected when configuring GCC, and, in the case of 32-bit PowerPC, if GCC is configured with `--enable-secureplt`. `-mpltseq` code and `-mbss-plt` 32-bit PowerPC relocatable objects may not be linked together.

`-mtls-markers`
`-mno-tls-markers`

Mark (do not mark) calls to `__tls_get_addr` with a relocation specifying the function argument. The relocation allows the linker to reliably associate function call with argument setup instructions for TLS optimization, which in turn allows GCC to better schedule the sequence.

`-mrecip`
`-mno-recip`

This option enables use of the reciprocal estimate and reciprocal square root estimate instructions with additional Newton-Raphson steps to increase precision instead of doing a divide or square root and divide for floating-point arguments. You should use the `-ffast-math` option when using `-mrecip` (or at least `-funsafe-math-optimizations`, `-ffinite-math-only`, `-freciprocal-math` and `-fno-trapping-math`). Note that while the throughput of the sequence is generally higher than the throughput of the non-reciprocal instruction, the precision of the sequence can be decreased by up to 2 ulp (i.e. the inverse of 1.0 equals 0.99999994) for reciprocal square roots.

`-mrecip=`*opt*

This option controls which reciprocal estimate instructions may be used. *opt* is a comma-separated list of options, which may be preceded by a `!` to invert the option:

‘`all`’ Enable all estimate instructions.

‘`default`’ Enable the default instructions, equivalent to `-mrecip`.

‘`none`’ Disable all estimate instructions, equivalent to `-mno-recip`.

‘`div`’ Enable the reciprocal approximation instructions for both single and double precision.

‘`divf`’ Enable the single-precision reciprocal approximation instructions.

‘`divd`’ Enable the double-precision reciprocal approximation instructions.

‘`rsqrt`’ Enable the reciprocal square root approximation instructions for both single and double precision.

‘`rsqrtf`’ Enable the single-precision reciprocal square root approximation instructions.

‘`rsqrtd`’ Enable the double-precision reciprocal square root approximation instructions.

So, for example, `-mrecip=all,!rsqrtd` enables all of the reciprocal estimate instructions, except for the `FRSQRTE`, `XSRSQRTEDP`, and `XVRSQRTEDP` instructions which handle the double-precision reciprocal square root calculations.

`-mrecip-precision`
`-mno-recip-precision`

Assume (do not assume) that the reciprocal estimate instructions provide higher-precision estimates than is mandated by the PowerPC ABI. Selecting `-mcpu=power6`, `-mcpu=power7` or `-mcpu=power8` automatically selects `-mrecip-precision`. The double-precision square root estimate instructions are not generated by default on low-precision machines, since they do not provide an estimate that converges after three steps.

`-mveclibabi=`*type*

Specifies the ABI type to use for vectorizing intrinsics using an external library. The only type supported at present is ‘`mass`’, which specifies to use

IBM's Mathematical Acceleration Subsystem (MASS) libraries for vectorizing intrinsics using external libraries. GCC currently emits calls to `acosd2`, `acosf4`, `acoshd2`, `acoshf4`, `asind2`, `asinf4`, `asinhd2`, `asinhf4`, `atan2d2`, `atan2f4`, `atand2`, `atanf4`, `atanhd2`, `atanhf4`, `cbrtd2`, `cbrtf4`, `cosd2`, `cosf4`, `coshd2`, `coshf4`, `erfcd2`, `erfcf4`, `erfd2`, `erff4`, `exp2d2`, `exp2f4`, `expd2`, `expf4`, `expm1d2`, `expm1f4`, `hypotd2`, `hypotf4`, `lgammad2`, `lgammaf4`, `log10d2`, `log10f4`, `log1pd2`, `log1pf4`, `log2d2`, `log2f4`, `logd2`, `logf4`, `powd2`, `powf4`, `sind2`, `sinf4`, `sinhd2`, `sinhf4`, `sqrtd2`, `sqrtf4`, `tand2`, `tanf4`, `tanhd2`, and `tanhf4` when generating code for power7. Both `-ftree-vectorize` and `-funsafe-math-optimizations` must also be enabled. The MASS libraries must be specified at link time.

`-mfriz`
`-mno-friz`
Generate (do not generate) the `friz` instruction when the `-funsafe-math-optimizations` option is used to optimize rounding of floating-point values to 64-bit integer and back to floating point. The `friz` instruction does not return the same value if the floating-point number is too large to fit in an integer.

`-mpointers-to-nested-functions`
`-mno-pointers-to-nested-functions`
Generate (do not generate) code to load up the static chain register (`r11`) when calling through a pointer on AIX and 64-bit Linux systems where a function pointer points to a 3-word descriptor giving the function address, TOC value to be loaded in register `r2`, and static chain value to be loaded in register `r11`. The `-mpointers-to-nested-functions` is on by default. You cannot call through pointers to nested functions or pointers to functions compiled in other languages that use the static chain if you use `-mno-pointers-to-nested-functions`.

`-msave-toc-indirect`
`-mno-save-toc-indirect`
Generate (do not generate) code to save the TOC value in the reserved stack location in the function prologue if the function calls through a pointer on AIX and 64-bit Linux systems. If the TOC value is not saved in the prologue, it is saved just before the call through the pointer. The `-mno-save-toc-indirect` option is the default.

`-mcompat-align-parm`
`-mno-compat-align-parm`
Generate (do not generate) code to pass structure parameters with a maximum alignment of 64 bits, for compatibility with older versions of GCC.

Older versions of GCC (prior to 4.9.0) incorrectly did not align a structure parameter on a 128-bit boundary when that structure contained a member requiring 128-bit alignment. This is corrected in more recent versions of GCC. This option may be used to generate code that is compatible with functions compiled with older versions of GCC.

The `-mno-compat-align-parm` option is the default.

`-mstack-protector-guard=`*guard*
`-mstack-protector-guard-reg=`*reg*
`-mstack-protector-guard-offset=`*offset*

Generate stack protection code using canary at *guard*. Supported locations are '`global`' for global canary or '`tls`' for per-thread canary in the TLS block (the default with GNU libc version 2.4 or later).

With the latter choice the options `-mstack-protector-guard-reg=`*reg* and `-mstack-protector-guard-offset=`*offset* furthermore specify which register to use as base register for reading the canary, and from what offset from that base register. The default for those is as specified in the relevant ABI.

`-mpcrel`
`-mno-pcrel`

Generate (do not generate) pc-relative addressing. The `-mpcrel` option requires that the medium code model (`-mcmodel=medium`) and prefixed addressing (`-mprefixed`) options are enabled.

`-mprefixed`
`-mno-prefixed`

Generate (do not generate) addressing modes using prefixed load and store instructions. The `-mprefixed` option requires that the option `-mcpu=power10` (or later) is enabled.

`-mmma`
`-mno-mma`

Generate (do not generate) the MMA instructions. The `-mma` option requires that the option `-mcpu=power10` (or later) is enabled.

`-mrop-protect`
`-mno-rop-protect`

Generate (do not generate) ROP protection instructions when the target processor supports them. Currently this option disables the shrink-wrap optimization (`-fshrink-wrap`).

`-mprivileged`
`-mno-privileged`

Generate (do not generate) code that will run in privileged state.

`-mblock-ops-unaligned-vsx`
`-mno-block-ops-unaligned-vsx`

Generate (do not generate) unaligned vsx loads and stores for inline expansion of `memcpy` and `memmove`.

`--param rs6000-vect-unroll-limit=`

The vectorizer will check with target information to determine whether it would be beneficial to unroll the main vectorized loop and by how much. This parameter sets the upper bound of how much the vectorizer will unroll the main loop. The default value is four.

3.20.43 RX Options

These command-line options are defined for RX targets:

`-m64bit-doubles`
`-m32bit-doubles`

Make the `double` data type be 64 bits (`-m64bit-doubles`) or 32 bits (`-m32bit-doubles`) in size. The default is `-m32bit-doubles`. *Note* RX floating-point hardware only works on 32-bit values, which is why the default is `-m32bit-doubles`.

`-fpu`
`-nofpu`

Enables (`-fpu`) or disables (`-nofpu`) the use of RX floating-point hardware. The default is enabled for the RX600 series and disabled for the RX200 series.

Floating-point instructions are only generated for 32-bit floating-point values, however, so the FPU hardware is not used for doubles if the `-m64bit-doubles` option is used.

Note If the `-fpu` option is enabled then `-funsafe-math-optimizations` is also enabled automatically. This is because the RX FPU instructions are themselves unsafe.

`-mcpu=`*name*

Selects the type of RX CPU to be targeted. Currently three types are supported, the generic '`RX600`' and '`RX200`' series hardware and the specific '`RX610`' CPU. The default is '`RX600`'.

The only difference between '`RX600`' and '`RX610`' is that the '`RX610`' does not support the `MVTIPL` instruction.

The '`RX200`' series does not have a hardware floating-point unit and so `-nofpu` is enabled by default when this type is selected.

`-mbig-endian-data`
`-mlittle-endian-data`

Store data (but not code) in the big-endian format. The default is `-mlittle-endian-data`, i.e. to store data in the little-endian format.

`-msmall-data-limit=`*N*

Specifies the maximum size in bytes of global and static variables which can be placed into the small data area. Using the small data area can lead to smaller and faster code, but the size of area is limited and it is up to the programmer to ensure that the area does not overflow. Also when the small data area is used one of the RX's registers (usually `r13`) is reserved for use pointing to this area, so it is no longer available for use by the compiler. This could result in slower and/or larger code if variables are pushed onto the stack instead of being held in this register.

Note, common variables (variables that have not been initialized) and constants are not placed into the small data area as they are assigned to other sections in the output executable.

The default value is zero, which disables this feature. Note, this feature is not enabled by default with higher optimization levels (`-O2` etc) because of the potentially detrimental effects of reserving a register. It is up to the programmer to experiment and discover whether this feature is of benefit to their program.

See the description of the `-mpid` option for a description of how the actual register to hold the small data area pointer is chosen.

`-msim`
`-mno-sim` Use the simulator runtime. The default is to use the libgloss board-specific runtime.

`-mas100-syntax`
`-mno-as100-syntax`
When generating assembler output use a syntax that is compatible with Renesas's AS100 assembler. This syntax can also be handled by the GAS assembler, but it has some restrictions so it is not generated by default.

`-mmax-constant-size=N`
Specifies the maximum size, in bytes, of a constant that can be used as an operand in a RX instruction. Although the RX instruction set does allow constants of up to 4 bytes in length to be used in instructions, a longer value equates to a longer instruction. Thus in some circumstances it can be beneficial to restrict the size of constants that are used in instructions. Constants that are too big are instead placed into a constant pool and referenced via register indirection.

The value *N* can be between 0 and 4. A value of 0 (the default) or 4 means that constants of any size are allowed.

`-mrelax` Enable linker relaxation. Linker relaxation is a process whereby the linker attempts to reduce the size of a program by finding shorter versions of various instructions. Disabled by default.

`-mint-register=N`
Specify the number of registers to reserve for fast interrupt handler functions. The value *N* can be between 0 and 4. A value of 1 means that register `r13` is reserved for the exclusive use of fast interrupt handlers. A value of 2 reserves `r13` and `r12`. A value of 3 reserves `r13`, `r12` and `r11`, and a value of 4 reserves `r13` through `r10`. A value of 0, the default, does not reserve any registers.

`-msave-acc-in-interrupts`
Specifies that interrupt handler functions should preserve the accumulator register. This is only necessary if normal code might use the accumulator register, for example because it performs 64-bit multiplications. The default is to ignore the accumulator as this makes the interrupt handlers faster.

`-mpid`
`-mno-pid` Enables the generation of position independent data. When enabled any access to constant data is done via an offset from a base address held in a register. This allows the location of constant data to be determined at run time without requiring the executable to be relocated, which is a benefit to embedded applications with tight memory constraints. Data that can be modified is not affected by this option.

Note, using this feature reserves a register, usually `r13`, for the constant data base address. This can result in slower and/or larger code, especially in complicated functions.

The actual register chosen to hold the constant data base address depends upon whether the `-msmall-data-limit` and/or the `-mint-register` command-line options are enabled. Starting with register `r13` and proceeding downwards, registers are allocated first to satisfy the requirements of `-mint-register`, then `-mpid` and finally `-msmall-data-limit`. Thus it is possible for the small data area register to be `r8` if both `-mint-register=4` and `-mpid` are specified on the command line.

By default this feature is not enabled. The default can be restored via the `-mno-pid` command-line option.

`-mno-warn-multiple-fast-interrupts`
`-mwarn-multiple-fast-interrupts`
: Prevents GCC from issuing a warning message if it finds more than one fast interrupt handler when it is compiling a file. The default is to issue a warning for each extra fast interrupt handler found, as the RX only supports one such interrupt.

`-mallow-string-insns`
`-mno-allow-string-insns`
: Enables or disables the use of the string manipulation instructions `SMOVF`, `SCMPU`, `SMOVB`, `SMOVU`, `SUNTIL` `SWHILE` and also the `RMPA` instruction. These instructions may prefetch data, which is not safe to do if accessing an I/O register. (See section 12.2.7 of the RX62N Group User's Manual for more information).

The default is to allow these instructions, but it is not possible for GCC to reliably detect all circumstances where a string instruction might be used to access an I/O register, so their use cannot be disabled automatically. Instead it is reliant upon the programmer to use the `-mno-allow-string-insns` option if their program accesses I/O space.

When the instructions are enabled GCC defines the C preprocessor symbol `__RX_ALLOW_STRING_INSNS__`, otherwise it defines the symbol `__RX_DISALLOW_STRING_INSNS__`.

`-mjsr`
`-mno-jsr`
: Use only (or not only) `JSR` instructions to access functions. This option can be used when code size exceeds the range of `BSR` instructions. Note that `-mno-jsr` does not mean to not use `JSR` but instead means that any type of branch may be used.

Note: The generic GCC command-line option `-ffixed-`*reg* has special significance to the RX port when used with the `interrupt` function attribute. This attribute indicates a function intended to process fast interrupts. GCC ensures that it only uses the registers `r10`, `r11`, `r12` and/or `r13` and only provided that the normal use of the corresponding registers have been restricted via the `-ffixed-`*reg* or `-mint-register` command-line options.

3.20.44 S/390 and zSeries Options

These are the '`-m`' options defined for the S/390 and zSeries architecture.

`-mhard-float`
`-msoft-float`

Use (do not use) the hardware floating-point instructions and registers for floating-point operations. When `-msoft-float` is specified, functions in `libgcc.a` are used to perform floating-point operations. When `-mhard-float` is specified, the compiler generates IEEE floating-point instructions. This is the default.

`-mhard-dfp`
`-mno-hard-dfp`

Use (do not use) the hardware decimal-floating-point instructions for decimal-floating-point operations. When `-mno-hard-dfp` is specified, functions in `libgcc.a` are used to perform decimal-floating-point operations. When `-mhard-dfp` is specified, the compiler generates decimal-floating-point hardware instructions. This is the default for `-march=z9-ec` or higher.

`-mlong-double-64`
`-mlong-double-128`

These switches control the size of `long double` type. A size of 64 bits makes the `long double` type equivalent to the `double` type. This is the default.

`-mbackchain`
`-mno-backchain`

Store (do not store) the address of the caller's frame as backchain pointer into the callee's stack frame. A backchain may be needed to allow debugging using tools that do not understand DWARF call frame information. When `-mno-packed-stack` is in effect, the backchain pointer is stored at the bottom of the stack frame; when `-mpacked-stack` is in effect, the backchain is placed into the topmost word of the 96/160 byte register save area.

In general, code compiled with `-mbackchain` is call-compatible with code compiled with `-mno-backchain`; however, use of the backchain for debugging purposes usually requires that the whole binary is built with `-mbackchain`. Note that the combination of `-mbackchain`, `-mpacked-stack` and `-mhard-float` is not supported. In order to build a linux kernel use `-msoft-float`.

The default is to not maintain the backchain.

`-mpacked-stack`
`-mno-packed-stack`

Use (do not use) the packed stack layout. When `-mno-packed-stack` is specified, the compiler uses the all fields of the 96/160 byte register save area only for their default purpose; unused fields still take up stack space. When `-mpacked-stack` is specified, register save slots are densely packed at the top of the register save area; unused space is reused for other purposes, allowing for more efficient use of the available stack space. However, when `-mbackchain` is also in effect, the topmost word of the save area is always used to store the backchain, and the return address register is always saved two words below the backchain.

As long as the stack frame backchain is not used, code generated with `-mpacked-stack` is call-compatible with code generated with `-mno-packed-stack`. Note that some non-FSF releases of GCC 2.95 for S/390 or zSeries generated code that uses the stack frame backchain at run time, not just for debugging purposes. Such code is not call-compatible with code compiled with `-mpacked-stack`. Also, note that the combination of `-mbackchain`, `-mpacked-stack` and `-mhard-float` is not supported. In order to build a linux kernel use `-msoft-float`.

The default is to not use the packed stack layout.

`-msmall-exec`
`-mno-small-exec`
: Generate (or do not generate) code using the `bras` instruction to do subroutine calls. This only works reliably if the total executable size does not exceed 64k. The default is to use the `basr` instruction instead, which does not have this limitation.

`-m64`
`-m31`
: When `-m31` is specified, generate code compliant to the GNU/Linux for S/390 ABI. When `-m64` is specified, generate code compliant to the GNU/Linux for zSeries ABI. This allows GCC in particular to generate 64-bit instructions. For the '`s390`' targets, the default is `-m31`, while the '`s390x`' targets default to `-m64`.

`-mzarch`
`-mesa`
: When `-mzarch` is specified, generate code using the instructions available on z/Architecture. When `-mesa` is specified, generate code using the instructions available on ESA/390. Note that `-mesa` is not possible with `-m64`. When generating code compliant to the GNU/Linux for S/390 ABI, the default is `-mesa`. When generating code compliant to the GNU/Linux for zSeries ABI, the default is `-mzarch`.

`-mhtm`
`-mno-htm`
: The `-mhtm` option enables a set of builtins making use of instructions available with the transactional execution facility introduced with the IBM zEnterprise EC12 machine generation Section 7.13.33 [S/390 System z Built-in Functions], page 1024. `-mhtm` is enabled by default when using `-march=zEC12`.

`-mvx`
`-mno-vx`
: When `-mvx` is specified, generate code using the instructions available with the vector extension facility introduced with the IBM z13 machine generation. This option changes the ABI for some vector type values with regard to alignment and calling conventions. In case vector type values are being used in an ABI-relevant context a GAS '`.gnu_attribute`' command will be added to mark the resulting binary with the ABI used. `-mvx` is enabled by default when using `-march=z13`.

`-mzvector`
`-mno-zvector`
: The `-mzvector` option enables vector language extensions and builtins using instructions available with the vector extension facility introduced with the IBM z13 machine generation. This option adds support for '`vector`' to be used as a keyword to define vector type variables and arguments. '`vector`'

is only available when GNU extensions are enabled. It will not be expanded when requesting strict standard compliance e.g. with `-std=c99`. In addition to the GCC low-level builtins `-mzvector` enables a set of builtins added for compatibility with AltiVec-style implementations like Power and Cell. In order to make use of these builtins the header file `vecintrin.h` needs to be included. `-mzvector` is disabled by default.

`-mmvcle`
`-mno-mvcle`
Generate (or do not generate) code using the `mvcle` instruction to perform block moves. When `-mno-mvcle` is specified, use a `mvc` loop instead. This is the default unless optimizing for size.

`-mdebug`
`-mno-debug`
Print (or do not print) additional debug information when compiling. The default is to not print debug information.

`-march=`*cpu-type*
Generate code that runs on *cpu-type*, which is the name of a system representing a certain processor type. Possible values for *cpu-type* are '`z900`'/'`arch5`', '`z990`'/'`arch6`', '`z9-109`', '`z9-ec`'/'`arch7`', '`z10`'/'`arch8`', '`z196`'/'`arch9`', '`zEC12`', '`z13`'/'`arch11`', '`z14`'/'`arch12`', '`z15`'/'`arch13`', '`z16`'/'`arch14`', '`z17`'/'`arch15`', and '`native`'.

The default is `-march=z900`.

Specifying '`native`' as cpu type can be used to select the best architecture option for the host processor. `-march=native` has no effect if GCC does not recognize the processor.

`-mtune=`*cpu-type*
Tune to *cpu-type* everything applicable about the generated code, except for the ABI and the set of available instructions. The list of *cpu-type* values is the same as for `-march`. The default is the value used for `-march`.

`-mtpf-trace`
`-mno-tpf-trace`
Generate code that adds (does not add) in TPF OS specific branches to trace routines in the operating system. This option is off by default, even when compiling for the TPF OS.

`-mtpf-trace-skip`
`-mno-tpf-trace-skip`
Generate code that changes (does not change) the default branch targets enabled by `-mtpf-trace` to point to specialized trace routines providing the ability of selectively skipping function trace entries for the TPF OS. This option is off by default, even when compiling for the TPF OS and specifying `-mtpf-trace`.

`-mfused-madd`
`-mno-fused-madd`

Generate code that uses (does not use) the floating-point multiply and accumulate instructions. These instructions are generated by default if hardware floating point is used.

`-mwarn-framesize=`*`framesize`*

Emit a warning if the current function exceeds the given frame size. Because this is a compile-time check it doesn't need to be a real problem when the program runs. It is intended to identify functions that most probably cause a stack overflow. It is useful to be used in an environment with limited stack size e.g. the linux kernel.

`-mwarn-dynamicstack`

Emit a warning if the function calls `alloca` or uses dynamically-sized arrays. This is generally a bad idea with a limited stack size.

`-mstack-guard=`*`stack-guard`*
`-mstack-size=`*`stack-size`*

If these options are provided the S/390 back end emits additional instructions in the function prologue that trigger a trap if the stack size is *stack-guard* bytes above the *stack-size* (remember that the stack on S/390 grows downward). If the *stack-guard* option is omitted the smallest power of 2 larger than the frame size of the compiled function is chosen. These options are intended to be used to help debugging stack overflow problems. The additionally emitted code causes only little overhead and hence can also be used in production-like systems without greater performance degradation. The given values have to be exact powers of 2 and *stack-size* has to be greater than *stack-guard* without exceeding 64k. In order to be efficient the extra code makes the assumption that the stack starts at an address aligned to the value given by *stack-size*. The *stack-guard* option can only be used in conjunction with *stack-size*.

`-mhotpatch=`*`pre-halfwords,post-halfwords`*

If the hotpatch option is enabled, a "hot-patching" function prologue is generated for all functions in the compilation unit. The funtion label is prepended with the given number of two-byte NOP instructions (*pre-halfwords*, maximum 1000000). After the label, 2 * *post-halfwords* bytes are appended, using the largest NOP like instructions the architecture allows (maximum 1000000).

If both arguments are zero, hotpatching is disabled.

This option can be overridden for individual functions with the `hotpatch` attribute.

`-mstack-protector-guard=`*`guard`*
`-mstack-protector-guard-record`

Generate stack protection code using canary at *guard*. Supported locations are *global* for a global canary or *tls* for a per-thread canary in the TLS block (the default).

Option `-mstack-protector-guard-record` results in the generation of section `__stack_protector_loc` containing pointers to all instructions which load the address of the global guard. Thus, this option has only an effect in conjunction with `-mstack-protector-guard=global`. The intended use is for the Linux kernel.

3.20.45 SH Options

These '`-m`' options are defined for the SH implementations:

`-m1` Generate code for the SH1.

`-m2` Generate code for the SH2.

`-m2e` Generate code for the SH2e.

`-m2a-nofpu`
: Generate code for the SH2a without FPU, or for a SH2a-FPU in such a way that the floating-point unit is not used.

`-m2a-single-only`
: Generate code for the SH2a-FPU, in such a way that no double-precision floating-point operations are used.

`-m2a-single`
: Generate code for the SH2a-FPU assuming the floating-point unit is in single-precision mode by default.

`-m2a` Generate code for the SH2a-FPU assuming the floating-point unit is in double-precision mode by default.

`-m3` Generate code for the SH3.

`-m3e` Generate code for the SH3e.

`-m4-nofpu`
: Generate code for the SH4 without a floating-point unit.

`-m4-single-only`
: Generate code for the SH4 with a floating-point unit that only supports single-precision arithmetic.

`-m4-single`
: Generate code for the SH4 assuming the floating-point unit is in single-precision mode by default.

`-m4` Generate code for the SH4.

`-m4-100` Generate code for SH4-100.

`-m4-100-nofpu`
: Generate code for SH4-100 in such a way that the floating-point unit is not used.

`-m4-100-single`
: Generate code for SH4-100 assuming the floating-point unit is in single-precision mode by default.

`-m4-100-single-only`
: Generate code for SH4-100 in such a way that no double-precision floating-point operations are used.

`-m4-200`
: Generate code for SH4-200.

`-m4-200-nofpu`
: Generate code for SH4-200 without in such a way that the floating-point unit is not used.

`-m4-200-single`
: Generate code for SH4-200 assuming the floating-point unit is in single-precision mode by default.

`-m4-200-single-only`
: Generate code for SH4-200 in such a way that no double-precision floating-point operations are used.

`-m4-300`
: Generate code for SH4-300.

`-m4-300-nofpu`
: Generate code for SH4-300 without in such a way that the floating-point unit is not used.

`-m4-300-single`
: Generate code for SH4-300 in such a way that no double-precision floating-point operations are used.

`-m4-300-single-only`
: Generate code for SH4-300 in such a way that no double-precision floating-point operations are used.

`-m4-340`
: Generate code for SH4-340 (no MMU, no FPU).

`-m4-500`
: Generate code for SH4-500 (no FPU). Passes `-isa=sh4-nofpu` to the assembler.

`-m4a-nofpu`
: Generate code for the SH4al-dsp, or for a SH4a in such a way that the floating-point unit is not used.

`-m4a-single-only`
: Generate code for the SH4a, in such a way that no double-precision floating-point operations are used.

`-m4a-single`
: Generate code for the SH4a assuming the floating-point unit is in single-precision mode by default.

`-m4a`
: Generate code for the SH4a.

`-m4al`
: Same as `-m4a-nofpu`, except that it implicitly passes `-dsp` to the assembler. GCC doesn't generate any DSP instructions at the moment.

`-mb`
: Compile code for the processor in big-endian mode.

`-ml`
: Compile code for the processor in little-endian mode.

`-mdalign` Align doubles at 64-bit boundaries. Note that this changes the calling conventions, and thus some functions from the standard C library do not work unless you recompile it first with `-mdalign`.

`-mrelax` Shorten some address references at link time, when possible; uses the linker option `-relax`.

`-mbigtable`
Use 32-bit offsets in `switch` tables. The default is to use 16-bit offsets.

`-mbitops` Enable the use of bit manipulation instructions on SH2A.

`-mfmovd` Enable the use of the instruction `fmovd`. Check `-mdalign` for alignment constraints.

`-mrenesas`
Comply with the calling conventions defined by Renesas.

`-mno-renesas`
Comply with the calling conventions defined for GCC before the Renesas conventions were available. This option is the default for all targets of the SH toolchain.

`-mnomacsave`
Mark the `MAC` register as call-clobbered, even if `-mrenesas` is given.

`-mieee`
`-mno-ieee`
Control the IEEE compliance of floating-point comparisons, which affects the handling of cases where the result of a comparison is unordered. By default `-mieee` is implicitly enabled. If `-ffinite-math-only` is enabled `-mno-ieee` is implicitly set, which results in faster floating-point greater-equal and less-equal comparisons. The implicit settings can be overridden by specifying either `-mieee` or `-mno-ieee`.

`-minline-ic_invalidate`
Inline code to invalidate instruction cache entries after setting up nested function trampolines. This option has no effect if `-musermode` is in effect and the selected code generation option (e.g. `-m4`) does not allow the use of the `icbi` instruction. If the selected code generation option does not allow the use of the `icbi` instruction, and `-musermode` is not in effect, the inlined code manipulates the instruction cache address array directly with an associative write. This not only requires privileged mode at run time, but it also fails if the cache line had been mapped via the TLB and has become unmapped.

`-misize` Dump instruction size and location in the assembly code.

`-mpadstruct`
This option is deprecated. It pads structures to multiple of 4 bytes, which is incompatible with the SH ABI.

`-matomic-model=`*`model`*
Sets the model of atomic operations and additional parameters as a comma separated list. For details on the atomic built-in functions see Section 7.9.1

[__atomic Builtins], page 854. The following models and parameters are supported:

'none' Disable compiler generated atomic sequences and emit library calls for atomic operations. This is the default if the target is not sh*-*-linux*.

'soft-gusa'
: Generate GNU/Linux compatible gUSA software atomic sequences for the atomic built-in functions. The generated atomic sequences require additional support from the interrupt/exception handling code of the system and are only suitable for SH3* and SH4* single-core systems. This option is enabled by default when the target is sh*-*-linux* and SH3* or SH4*. When the target is SH4A, this option also partially utilizes the hardware atomic instructions movli.l and movco.l to create more efficient code, unless 'strict' is specified.

'soft-tcb'
: Generate software atomic sequences that use a variable in the thread control block. This is a variation of the gUSA sequences which can also be used on SH1* and SH2* targets. The generated atomic sequences require additional support from the interrupt/exception handling code of the system and are only suitable for single-core systems. When using this model, the 'gbr-offset=' parameter has to be specified as well.

'soft-imask'
: Generate software atomic sequences that temporarily disable interrupts by setting SR.IMASK = 1111. This model works only when the program runs in privileged mode and is only suitable for single-core systems. Additional support from the interrupt/exception handling code of the system is not required. This model is enabled by default when the target is sh*-*-linux* and SH1* or SH2*.

'hard-llcs'
: Generate hardware atomic sequences using the movli.l and movco.l instructions only. This is only available on SH4A and is suitable for multi-core systems. Since the hardware instructions support only 32 bit atomic variables access to 8 or 16 bit variables is emulated with 32 bit accesses. Code compiled with this option is also compatible with other software atomic model interrupt/exception handling systems if executed on an SH4A system. Additional support from the interrupt/exception handling code of the system is not required for this model.

'gbr-offset='
: This parameter specifies the offset in bytes of the variable in the thread control block structure that should be used by the generated atomic sequences when the 'soft-tcb' model has been selected. For

other models this parameter is ignored. The specified value must be an integer multiple of four and in the range 0-1020.

'strict' This parameter prevents mixed usage of multiple atomic models, even if they are compatible, and makes the compiler generate atomic sequences of the specified model only.

-mtas Generate the tas.b opcode for __atomic_test_and_set. Notice that depending on the particular hardware and software configuration this can degrade overall performance due to the operand cache line flushes that are implied by the tas.b instruction. On multi-core SH4A processors the tas.b instruction must be used with caution since it can result in data corruption for certain cache configurations.

-mprefergot
When generating position-independent code, emit function calls using the Global Offset Table instead of the Procedure Linkage Table.

-musermode
-mno-usermode
Don't allow (allow) the compiler generating privileged mode code. Specifying -musermode also implies -mno-inline-ic_invalidate if the inlined code would not work in user mode. -musermode is the default when the target is sh*-*-linux*. If the target is SH1* or SH2* -musermode has no effect, since there is no user mode.

-multcost=*number*
Set the cost to assume for a multiply insn.

-mdiv=*strategy*
Set the division strategy to be used for integer division operations. *strategy* can be one of:

'call-div1'
Calls a library function that uses the single-step division instruction div1 to perform the operation. Division by zero calculates an unspecified result and does not trap. This is the default except for SH4, SH2A and SHcompact.

'call-fp' Calls a library function that performs the operation in double precision floating point. Division by zero causes a floating-point exception. This is the default for SHcompact with FPU. Specifying this for targets that do not have a double precision FPU defaults to call-div1.

'call-table'
Calls a library function that uses a lookup table for small divisors and the div1 instruction with case distinction for larger divisors. Division by zero calculates an unspecified result and does not trap. This is the default for SH4. Specifying this for targets that do not have dynamic shift instructions defaults to call-div1.

When a division strategy has not been specified the default strategy is selected based on the current target. For SH2A the default strategy is to use the `divs` and `divu` instructions instead of library function calls.

`-maccumulate-outgoing-args`
: Reserve space once for outgoing arguments in the function prologue rather than around each call. Generally beneficial for performance and size. Also needed for unwinding to avoid changing the stack frame around conditional code.

`-mdivsi3_libfunc=`*name*
: Set the name of the library function used for 32-bit signed division to *name*. This only affects the name used in the '`call`' division strategies, and the compiler still expects the same sets of input/output/clobbered registers as if this option were not present.

`-mfixed-range=`*register-range*
: Generate code treating the given register range as fixed registers. A fixed register is one that the register allocator cannot use. This is useful when compiling kernel code. A register range is specified as two registers separated by a dash. Multiple register ranges can be specified separated by a comma.

`-mbranch-cost=`*num*
: Assume *num* to be the cost for a branch instruction. Higher numbers make the compiler try to generate more branch-free code if possible. If not specified the value is selected depending on the processor type that is being compiled for.

`-mzdcbranch`
`-mno-zdcbranch`
: Assume (do not assume) that zero displacement conditional branch instructions `bt` and `bf` are fast. If `-mzdcbranch` is specified, the compiler prefers zero displacement branch code sequences. This is enabled by default when generating code for SH4 and SH4A. It can be explicitly disabled by specifying `-mno-zdcbranch`.

`-mcbranch-force-delay-slot`
: Force the usage of delay slots for conditional branches, which stuffs the delay slot with a `nop` if a suitable instruction cannot be found. By default this option is disabled. It can be enabled to work around hardware bugs as found in the original SH7055.

`-mfused-madd`
`-mno-fused-madd`
: Generate code that uses (does not use) the floating-point multiply and accumulate instructions. These instructions are generated by default if hardware floating point is used. The machine-dependent `-mfused-madd` option is now mapped to the machine-independent `-ffp-contract=fast` option, and `-mno-fused-madd` is mapped to `-ffp-contract=off`.

`-mfsca`
`-mno-fsca`
: Allow or disallow the compiler to emit the `fsca` instruction for sine and cosine approximations. The option `-mfsca` must be used in combination with

-funsafe-math-optimizations. It is enabled by default when generating code for SH4A. Using -mno-fsca disables sine and cosine approximations even if -funsafe-math-optimizations is in effect.

-mfsrra
-mno-fsrra
Allow or disallow the compiler to emit the fsrra instruction for reciprocal square root approximations. The option -mfsrra must be used in combination with -funsafe-math-optimizations and -ffinite-math-only. It is enabled by default when generating code for SH4A. Using -mno-fsrra disables reciprocal square root approximations even if -funsafe-math-optimizations and -ffinite-math-only are in effect.

-mpretend-cmove
Prefer zero-displacement conditional branches for conditional move instruction patterns. This can result in faster code on the SH4 processor.

-mfdpic Generate code using the FDPIC ABI.

3.20.46 Solaris 2 Options

These '-m' options are supported on Solaris 2:

-mclear-hwcap
-mclear-hwcap tells the compiler to remove the hardware capabilities generated by the Solaris assembler. This is only necessary when object files use ISA extensions not supported by the current machine, but check at runtime whether or not to use them.

-mimpure-text
-mimpure-text, used in addition to -shared, tells the compiler to not pass -z text to the linker when linking a shared object. Using this option, you can link position-dependent code into a shared object.

-mimpure-text suppresses the "relocations remain against allocatable but non-writable sections" linker error message. However, the necessary relocations trigger copy-on-write, and the shared object is not actually shared across processes. Instead of using -mimpure-text, you should compile all source code with -fpic or -fPIC.

These switches are supported in addition to the above on Solaris 2:

-pthreads
This is a synonym for -pthread.

3.20.47 SPARC Options

These '-m' options are supported on the SPARC:

-mno-app-regs
-mapp-regs
Specify -mapp-regs to generate output using the global registers 2 through 4, which the SPARC SVR4 ABI reserves for applications. Like the global register

1, each global register 2 through 4 is then treated as an allocable register that is clobbered by function calls. This is the default.

To be fully SVR4 ABI-compliant at the cost of some performance loss, specify `-mno-app-regs`. You should compile libraries and system software with this option.

`-mflat`
`-mno-flat`
: With `-mflat`, the compiler does not generate save/restore instructions and uses a "flat" or single register window model. This model is compatible with the regular register window model. The local registers and the input registers (0–5) are still treated as "call-saved" registers and are saved on the stack as needed.

  With `-mno-flat` (the default), the compiler generates save/restore instructions (except for leaf functions). This is the normal operating mode.

`-mfpu`
`-mhard-float`
: Generate output containing floating-point instructions. This is the default.

`-mno-fpu`
`-msoft-float`
: Generate output containing library calls for floating point. **Warning:** the requisite libraries are not available for all SPARC targets. Normally the facilities of the machine's usual C compiler are used, but this cannot be done directly in cross-compilation. You must make your own arrangements to provide suitable library functions for cross-compilation. The embedded targets '`sparc-*-aout`' and '`sparclite-*-*`' do provide software floating-point support.

  `-msoft-float` changes the calling convention in the output file; therefore, it is only useful if you compile *all* of a program with this option. In particular, you need to compile `libgcc.a`, the library that comes with GCC, with `-msoft-float` in order for this to work.

`-mhard-quad-float`
: Generate output containing quad-word (long double) floating-point instructions.

`-msoft-quad-float`
: Generate output containing library calls for quad-word (long double) floating-point instructions. The functions called are those specified in the SPARC ABI. This is the default.

  As of this writing, there are no SPARC implementations that have hardware support for the quad-word floating-point instructions. They all invoke a trap handler for one of these instructions, and then the trap handler emulates the effect of the instruction. Because of the trap handler overhead, this is much slower than calling the ABI library routines. Thus the `-msoft-quad-float` option is the default.

`-mno-unaligned-doubles`
`-munaligned-doubles`
: Assume that doubles have 8-byte alignment. This is the default.

With `-munaligned-doubles`, GCC assumes that doubles have 8-byte alignment only if they are contained in another type, or if they have an absolute address. Otherwise, it assumes they have 4-byte alignment. Specifying this option avoids some rare compatibility problems with code generated by other compilers. It is not the default because it results in a performance loss, especially for floating-point code.

`-muser-mode`
`-mno-user-mode`
: Do not generate code that can only run in supervisor mode. This is relevant only for the `casa` instruction emitted for the LEON3 processor. This is the default.

`-mfaster-structs`
`-mno-faster-structs`
: With `-mfaster-structs`, the compiler assumes that structures should have 8-byte alignment. This enables the use of pairs of `ldd` and `std` instructions for copies in structure assignment, in place of twice as many `ld` and `st` pairs. However, the use of this changed alignment directly violates the SPARC ABI. Thus, it's intended only for use on targets where the developer acknowledges that their resulting code is not directly in line with the rules of the ABI.

`-mstd-struct-return`
`-mno-std-struct-return`
: With `-mstd-struct-return`, the compiler generates checking code in functions returning structures or unions to detect size mismatches between the two sides of function calls, as per the 32-bit ABI.

The default is `-mno-std-struct-return`. This option has no effect in 64-bit mode.

`-mcpu=`*cpu_type*
: Set the instruction set, register set, and instruction scheduling parameters for machine type *cpu_type*. Supported values for *cpu_type* are '`v7`', '`cypress`', '`v8`', '`supersparc`', '`hypersparc`', '`leon`', '`leon3`', '`leon3v7`', '`leon5`', '`sparclite`', '`f930`', '`f934`', '`sparclite86x`', '`sparclet`', '`tsc701`', '`v9`', '`ultrasparc`', '`ultrasparc3`', '`niagara`', '`niagara2`', '`niagara3`', '`niagara4`', '`niagara7`' and '`m8`'.

Native Solaris and GNU/Linux toolchains also support the value '`native`', which selects the best architecture option for the host processor. `-mcpu=native` has no effect if GCC does not recognize the processor.

Default instruction scheduling parameters are used for values that select an architecture and not an implementation. These are '`v7`', '`v8`', '`sparclite`', '`sparclet`', '`v9`'.

Here is a list of each supported architecture and their supported implementations.

v7 cypress, leon3v7

v8 supersparc, hypersparc, leon, leon3, leon5 sparclite f930, f934, sparclite86x

sparclet tsc701

v9 ultrasparc, ultrasparc3, niagara, niagara2, niagara3, niagara4, niagara7, m8

By default (unless configured otherwise), GCC generates code for the V7 variant of the SPARC architecture. With `-mcpu=cypress`, the compiler additionally optimizes it for the Cypress CY7C602 chip, as used in the SPARCStation/SPARCServer 3xx series. This is also appropriate for the older SPARCStation 1, 2, IPX etc.

With `-mcpu=v8`, GCC generates code for the V8 variant of the SPARC architecture. The only difference from V7 code is that the compiler emits the integer multiply and integer divide instructions which exist in SPARC-V8 but not in SPARC-V7. With `-mcpu=supersparc`, the compiler additionally optimizes it for the SuperSPARC chip, as used in the SPARCStation 10, 1000 and 2000 series.

With `-mcpu=sparclite`, GCC generates code for the SPARClite variant of the SPARC architecture. This adds the integer multiply, integer divide step and scan (`ffs`) instructions which exist in SPARClite but not in SPARC-V7. With `-mcpu=f930`, the compiler additionally optimizes it for the Fujitsu MB86930 chip, which is the original SPARClite, with no FPU. With `-mcpu=f934`, the compiler additionally optimizes it for the Fujitsu MB86934 chip, which is the more recent SPARClite with FPU.

With `-mcpu=sparclet`, GCC generates code for the SPARClet variant of the SPARC architecture. This adds the integer multiply, multiply/accumulate, integer divide step and scan (`ffs`) instructions which exist in SPARClet but not in SPARC-V7. With `-mcpu=tsc701`, the compiler additionally optimizes it for the TEMIC SPARClet chip.

With `-mcpu=v9`, GCC generates code for the V9 variant of the SPARC architecture. This adds 64-bit integer and floating-point move instructions, 3 additional floating-point condition code registers and conditional move instructions. With `-mcpu=ultrasparc`, the compiler additionally optimizes it for the Sun UltraSPARC I/II/IIi chips. With `-mcpu=ultrasparc3`, the compiler additionally optimizes it for the Sun UltraSPARC III/III+/IIIi/IIIi+/IV/IV+ chips. With `-mcpu=niagara`, the compiler additionally optimizes it for Sun UltraSPARC T1 chips. With `-mcpu=niagara2`, the compiler additionally optimizes it for Sun UltraSPARC T2 chips. With `-mcpu=niagara3`, the compiler additionally optimizes it for Sun UltraSPARC T3 chips. With `-mcpu=niagara4`, the compiler additionally optimizes it for Sun UltraSPARC T4 chips. With `-mcpu=niagara7`, the compiler additionally optimizes it for Oracle SPARC M7 chips. With `-mcpu=m8`, the compiler additionally optimizes it for Oracle M8 chips.

`-mtune=`*`cpu_type`*

Set the instruction scheduling parameters for machine type *cpu_type*, but do not set the instruction set or register set that the option `-mcpu=`*`cpu_type`* does.

The same values for `-mcpu=cpu_type` can be used for `-mtune=cpu_type`, but the only useful values are those that select a particular CPU implementation. Those are '`cypress`', '`supersparc`', '`hypersparc`', '`leon`', '`leon3`', '`leon3v7`', '`leon5`', '`f930`', '`f934`', '`sparclite86x`', '`tsc701`', '`ultrasparc`', '`ultrasparc3`', '`niagara`', '`niagara2`', '`niagara3`', '`niagara4`', '`niagara7`' and '`m8`'. With native Solaris and GNU/Linux toolchains, '`native`' can also be used.

`-mv8plus`
`-mno-v8plus`
: With `-mv8plus`, GCC generates code for the SPARC-V8+ ABI. The difference from the V8 ABI is that the global and out registers are considered 64 bits wide. This is enabled by default on Solaris in 32-bit mode for all SPARC-V9 processors.

`-mvis`
`-mno-vis`
: With `-mvis`, GCC generates code that takes advantage of the UltraSPARC Visual Instruction Set extensions. The default is `-mno-vis`.

`-mvis2`
`-mno-vis2`
: With `-mvis2`, GCC generates code that takes advantage of version 2.0 of the UltraSPARC Visual Instruction Set extensions. The default is `-mvis2` when targeting a cpu that supports such instructions, such as UltraSPARC-III and later. Setting `-mvis2` also sets `-mvis`.

`-mvis3`
`-mno-vis3`
: With `-mvis3`, GCC generates code that takes advantage of version 3.0 of the UltraSPARC Visual Instruction Set extensions. The default is `-mvis3` when targeting a cpu that supports such instructions, such as niagara-3 and later. Setting `-mvis3` also sets `-mvis2` and `-mvis`.

`-mvis3b`
`-mno-vis3b`
: With `-mvis3b`, GCC generates code that takes advantage of version 3.0 of the UltraSPARC Visual Instruction Set extensions, plus the additional VIS instructions introduced in the Oracle SPARC Architecture 2011. The default is `-mvis3b` when targeting a cpu that supports such instructions, such as niagara-7 and later. Setting `-mvis3b` also sets `-mvis3`, `-mvis2` and `-mvis`.

`-mvis4`
`-mno-vis4`
: With `-mvis4`, GCC generates code that takes advantage of version 4.0 of the UltraSPARC Visual Instruction Set extensions. The default is `-mvis4` when targeting a cpu that supports such instructions, such as niagara-7 and later. Setting `-mvis4` also sets `-mvis3b`, `-mvis3`, `-mvis2` and `-mvis`.

`-mvis4b`
`-mno-vis4b`
With `-mvis4b`, GCC generates code that takes advantage of version 4.0 of the UltraSPARC Visual Instruction Set extensions, plus the additional VIS instructions introduced in the Oracle SPARC Architecture 2017. The default is `-mvis4b` when targeting a cpu that supports such instructions, such as m8 and later. Setting `-mvis4b` also sets `-mvis4`, `-mvis3b`, `-mvis3`, `-mvis2` and `-mvis`.

`-mcbcond`
`-mno-cbcond`
With `-mcbcond`, GCC generates code that takes advantage of the UltraSPARC Compare-and-Branch-on-Condition instructions. The default is `-mcbcond` when targeting a CPU that supports such instructions, such as Niagara-4 and later.

`-mfmaf`
`-mno-fmaf`
With `-mfmaf`, GCC generates code that takes advantage of the UltraSPARC Fused Multiply-Add Floating-point instructions. The default is `-mfmaf` when targeting a CPU that supports such instructions, such as Niagara-3 and later.

`-mfsmuld`
`-mno-fsmuld`
With `-mfsmuld`, GCC generates code that takes advantage of the Floating-point Multiply Single to Double (FsMULd) instruction. The default is `-mfsmuld` when targeting a CPU supporting the architecture versions V8 or V9 with FPU except `-mcpu=leon`.

`-mpopc`
`-mno-popc`
With `-mpopc`, GCC generates code that takes advantage of the UltraSPARC Population Count instruction. The default is `-mpopc` when targeting a CPU that supports such an instruction, such as Niagara-2 and later.

`-msubxc`
`-mno-subxc`
With `-msubxc`, GCC generates code that takes advantage of the UltraSPARC Subtract-Extended-with-Carry instruction. The default is `-msubxc` when targeting a CPU that supports such an instruction, such as Niagara-7 and later.

`-mfix-at697f`
Enable the documented workaround for the single erratum of the Atmel AT697F processor (which corresponds to erratum #13 of the AT697E processor).

`-mfix-ut699`
Enable the documented workarounds for the floating-point errata and the data cache nullify errata of the UT699 processor.

`-mfix-ut700`
Enable the documented workaround for the back-to-back store errata of the UT699E/UT700 processor.

`-mfix-gr712rc`
: Enable the documented workaround for the back-to-back store errata of the GR712RC processor.

These '`-m`' options are supported in addition to the above on SPARC-V9 processors in 64-bit environments:

`-m32`
`-m64`
: Generate code for a 32-bit or 64-bit environment. The 32-bit environment sets int, long and pointer to 32 bits. The 64-bit environment sets int to 32 bits and long and pointer to 64 bits.

`-mcmodel=`*`which`*
: Set the code model to one of

  '`medlow`' The Medium/Low code model: 64-bit addresses, programs must be linked in the low 32 bits of memory. Programs can be statically or dynamically linked.

  '`medmid`' The Medium/Middle code model: 64-bit addresses, programs must be linked in the low 44 bits of memory, the text and data segments must be less than 2GB in size and the data segment must be located within 2GB of the text segment.

  '`medany`' The Medium/Anywhere code model: 64-bit addresses, programs may be linked anywhere in memory, the text and data segments must be less than 2GB in size and the data segment must be located within 2GB of the text segment.

  '`embmedany`'
  The Medium/Anywhere code model for embedded systems: 64-bit addresses, the text and data segments must be less than 2GB in size, both starting anywhere in memory (determined at link time). The global register %g4 points to the base of the data segment. Programs are statically linked and PIC is not supported.

`-mmemory-model=`*`mem-model`*
: Set the memory model in force on the processor to one of

  '`default`' The default memory model for the processor and operating system.

  '`rmo`' Relaxed Memory Order

  '`pso`' Partial Store Order

  '`tso`' Total Store Order

  '`sc`' Sequential Consistency

  These memory models are formally defined in Appendix D of the SPARC-V9 architecture manual, as set in the processor's `PSTATE.MM` field.

`-mstack-bias`
`-mno-stack-bias`
: With `-mstack-bias`, GCC assumes that the stack pointer, and frame pointer if present, are offset by −2047 which must be added back when making stack

frame references. This is the default in 64-bit mode. Otherwise, assume no such offset is present.

3.20.48 Options for System V

These additional options are available on System V Release 4 for compatibility with other compilers on those systems:

`-G` Create a shared object. It is recommended that `-symbolic` or `-shared` be used instead.

`-YP,dirs` Search the directories *dirs*, and no others, for libraries specified with `-l`.

`-Ym,dir` Look in the directory *dir* to find the M4 preprocessor. The assembler uses this option.

3.20.49 V850 Options

These '`-m`' options are defined for V850 implementations:

`-mlong-calls`
`-mno-long-calls`
Treat all calls as being far away (near). If calls are assumed to be far away, the compiler always loads the function's address into a register, and calls indirect through the pointer.

`-mno-ep`
`-mep` Do not optimize (do optimize) basic blocks that use the same index pointer 4 or more times to copy pointer into the `ep` register, and use the shorter `sld` and `sst` instructions. The `-mep` option is on by default if you optimize.

`-mno-prolog-function`
`-mprolog-function`
Do not use (do use) external functions to save and restore registers at the prologue and epilogue of a function. The external functions are slower, but use less code space if more than one function saves the same number of registers. The `-mprolog-function` option is on by default if you optimize.

`-mspace` Try to make the code as small as possible. At present, this just turns on the `-mep` and `-mprolog-function` options.

`-mtda=n` Put static or global variables whose size is *n* bytes or less into the tiny data area that register `ep` points to. The tiny data area can hold up to 256 bytes in total (128 bytes for byte references).

`-msda=n` Put static or global variables whose size is *n* bytes or less into the small data area that register `gp` points to. The small data area can hold up to 64 kilobytes.

`-mzda=n` Put static or global variables whose size is *n* bytes or less into the first 32 kilobytes of memory.

`-mv850` Specify that the target processor is the V850.

`-mv850e3v5`
Specify that the target processor is the V850E3V5. The preprocessor constant `__v850e3v5__` is defined if this option is used.

`-mv850e2v4`
: Specify that the target processor is the V850E3V5. This is an alias for the `-mv850e3v5` option.

`-mv850e2v3`
: Specify that the target processor is the V850E2V3. The preprocessor constant `__v850e2v3__` is defined if this option is used.

`-mv850e2`
: Specify that the target processor is the V850E2. The preprocessor constant `__v850e2__` is defined if this option is used.

`-mv850e1`
: Specify that the target processor is the V850E1. The preprocessor constants `__v850e1__` and `__v850e__` are defined if this option is used.

`-mv850es`
: Specify that the target processor is the V850ES. This is an alias for the `-mv850e1` option.

`-mv850e`
: Specify that the target processor is the V850E. The preprocessor constant `__v850e__` is defined if this option is used.

If neither `-mv850` nor `-mv850e` nor `-mv850e1` nor `-mv850e2` nor `-mv850e2v3` nor `-mv850e3v5` are defined then a default target processor is chosen and the relevant '`__v850*__`' preprocessor constant is defined.

The preprocessor constants `__v850` and `__v851__` are always defined, regardless of which processor variant is the target.

`-mdisable-callt`
`-mno-disable-callt`
: This option suppresses generation of the `CALLT` instruction for the v850e, v850e1, v850e2, v850e2v3 and v850e3v5 flavors of the v850 architecture.

This option is enabled by default when the RH850 ABI is in use (see `-mrh850-abi`), and disabled by default when the GCC ABI is in use. If `CALLT` instructions are being generated then the C preprocessor symbol `__V850_CALLT__` is defined.

`-mrelax`
`-mno-relax`
: Pass on (or do not pass on) the `-mrelax` command-line option to the assembler.

`-mlong-jumps`
`-mno-long-jumps`
: Disable (or re-enable) the generation of PC-relative jump instructions.

`-msoft-float`
`-mhard-float`
: Disable (or re-enable) the generation of hardware floating point instructions. This option is only significant when the target architecture is '`V850E2V3`' or higher. If hardware floating point instructions are being generated then the C preprocessor symbol `__FPU_OK__` is defined, otherwise the symbol `__NO_FPU__` is defined.

`-mloop`
: Enables the use of the e3v5 LOOP instruction. The use of this instruction is not enabled by default when the e3v5 architecture is selected because its use is still experimental.

`-mrh850-abi`
`-mghs`
: Enables support for the RH850 version of the V850 ABI. This is the default. With this version of the ABI the following rules apply:
  - Integer sized structures and unions are returned via a memory pointer rather than a register.
  - Large structures and unions (more than 8 bytes in size) are passed by value.
  - Functions are aligned to 16-bit boundaries.
  - The `-m8byte-align` command-line option is supported.
  - The `-mdisable-callt` command-line option is enabled by default. The `-mno-disable-callt` command-line option is not supported.

  When this version of the ABI is enabled the C preprocessor symbol `__V850_RH850_ABI__` is defined.

`-mgcc-abi`
: Enables support for the old GCC version of the V850 ABI. With this version of the ABI the following rules apply:
  - Integer sized structures and unions are returned in register `r10`.
  - Large structures and unions (more than 8 bytes in size) are passed by reference.
  - Functions are aligned to 32-bit boundaries, unless optimizing for size.
  - The `-m8byte-align` command-line option is not supported.
  - The `-mdisable-callt` command-line option is supported but not enabled by default.

  When this version of the ABI is enabled the C preprocessor symbol `__V850_GCC_ABI__` is defined.

`-m8byte-align`
`-mno-8byte-align`
: Enables support for `double` and `long long` types to be aligned on 8-byte boundaries. The default is to restrict the alignment of all objects to at most 4-bytes. When `-m8byte-align` is in effect the C preprocessor symbol `__V850_8BYTE_ALIGN__` is defined.

`-mbig-switch`
: Generate code suitable for big switch tables. Use this option only if the assembler/linker complain about out of range branches within a switch table.

`-mapp-regs`
: This option causes r2 and r5 to be used in the code generated by the compiler. This setting is the default.

`-mno-app-regs`
: This option causes r2 and r5 to be treated as fixed registers.

3.20.50 VAX Options

These '`-m`' options are defined for the VAX:

`-munix`
: Do not output certain jump instructions (`aobleq` and so on) that the Unix assembler for the VAX cannot handle across long ranges.

`-mgnu` Do output those jump instructions, on the assumption that the GNU assembler is being used.

`-md`
`-md-float`
Use the D_floating data format for double-precision floating-point numbers instead of G_floating.

`-mg`
`-mg-float`
Use the G_floating data format for double-precision floating-point numbers instead of D_floating.

`-mlra`
`-mno-lra` Enable Local Register Allocation. This is still experimental for the VAX, so by default the compiler uses standard reload.

3.20.51 Visium Options

`-mdebug` A program which performs file I/O and is destined to run on an MCM target should be linked with this option. It causes the libraries libc.a and libdebug.a to be linked. The program should be run on the target under the control of the GDB remote debugging stub.

`-msim` A program which performs file I/O and is destined to run on the simulator should be linked with option. This causes libraries libc.a and libsim.a to be linked.

`-mfpu`
`-mhard-float`
Generate code containing floating-point instructions. This is the default.

`-mno-fpu`
`-msoft-float`
Generate code containing library calls for floating-point.

`-msoft-float` changes the calling convention in the output file; therefore, it is only useful if you compile *all* of a program with this option. In particular, you need to compile `libgcc.a`, the library that comes with GCC, with `-msoft-float` in order for this to work.

`-mcpu=`*`cpu_type`*
Set the instruction set, register set, and instruction scheduling parameters for machine type *cpu_type*. Supported values for *cpu_type* are '`mcm`', '`gr5`' and '`gr6`'.

'`mcm`' is a synonym of '`gr5`' present for backward compatibility.

By default (unless configured otherwise), GCC generates code for the GR5 variant of the Visium architecture.

With `-mcpu=gr6`, GCC generates code for the GR6 variant of the Visium architecture. The only difference from GR5 code is that the compiler will generate block move instructions.

`-mtune=cpu_type`
Set the instruction scheduling parameters for machine type *cpu_type*, but do not set the instruction set or register set that the option `-mcpu=cpu_type` would.

`-msv-mode`
Generate code for the supervisor mode, where there are no restrictions on the access to general registers. This is the default.

`-muser-mode`
Generate code for the user mode, where the access to some general registers is forbidden: on the GR5, registers r24 to r31 cannot be accessed in this mode; on the GR6, only registers r29 to r31 are affected.

3.20.52 VMS Options

These '`-m`' options are defined for the VMS implementations:

`-mvms-return-codes`
Return VMS condition codes from `main`. The default is to return POSIX-style condition (e.g. error) codes.

`-mdebug-main=prefix`
Flag the first routine whose name starts with *prefix* as the main routine for the debugger.

`-mmalloc64`
Default to 64-bit memory allocation routines.

`-mpointer-size=size`
Set the default size of pointers. Possible options for *size* are '`32`' or '`short`' for 32 bit pointers, '`64`' or '`long`' for 64 bit pointers, and '`no`' for supporting only 32 bit pointers. The later option disables `pragma pointer_size`.

3.20.53 VxWorks Options

The options in this section are defined for all VxWorks targets. Options specific to the target hardware are listed with the other options for that target.

`-mrtp` GCC can generate code for both VxWorks kernels and real time processes (RTPs). This option switches from the former to the latter. It also defines the preprocessor macro `__RTP__`.

`-msmp` Select SMP runtimes for linking. Not available on architectures other than PowerPC, nor on VxWorks version 7 or later, in which the selection is part of the VxWorks build configuration and the library paths are the same for either choice.

`-non-static`
Link an RTP executable against shared libraries rather than static libraries. The options `-static` and `-shared` can also be used for RTPs (see Section 3.16 [Link Options], page 305); `-static` is the default.

`-Bstatic`
`-Bdynamic`
: These options are passed down to the linker. They are defined for compatibility with Diab.

`-Xbind-lazy`
: Enable lazy binding of function calls. This option is equivalent to `-Wl,-z,now` and is defined for compatibility with Diab.

`-Xbind-now`
: Disable lazy binding of function calls. This option is the default and is defined for compatibility with Diab.

3.20.54 x86 Options

These '`-m`' options are defined for the x86 family of computers.

`-march=`*`cpu-type`*
: Generate instructions for the machine type *cpu-type*. In contrast to `-mtune=`*`cpu-type`*, which merely tunes the generated code for the specified *cpu-type*, `-march=`*`cpu-type`* allows GCC to generate code that may not run at all on processors other than the one indicated. Specifying `-march=`*`cpu-type`* implies `-mtune=`*`cpu-type`*, except where noted otherwise.

The choices for *cpu-type* are:

'`native`'
: This selects the CPU to generate code for at compilation time by determining the processor type of the compiling machine. Using `-march=native` enables all instruction subsets supported by the local machine (hence the result might not run on different machines). Using `-mtune=native` produces code optimized for the local machine under the constraints of the selected instruction set.

'`x86-64`'
: A generic CPU with 64-bit extensions, MMX, SSE, SSE2, and FXSR instruction set support.

'`x86-64-v2`'
'`x86-64-v3`'
'`x86-64-v4`'
: These choices for *cpu-type* select the corresponding micro-architecture level from the x86-64 psABI. On ABIs other than the x86-64 psABI they select the same CPU features as the x86-64 psABI documents for the particular micro-architecture level.

Since these *cpu-type* values do not have a corresponding `-mtune` setting, using `-march` with these values enables generic tuning. Specific tuning can be enabled using the `-mtune=`*`other-cpu-type`* option with an appropriate *other-cpu-type* value.

'`i386`'
: Original Intel i386 CPU.

'`i486`'
: Intel i486 CPU. (No scheduling is implemented for this chip.)

'`i586`'
'`pentium`'
: Intel Pentium CPU with no MMX support.

'lakemont'
: Intel Lakemont MCU, based on Intel Pentium CPU.

'pentium-mmx'
: Intel Pentium MMX CPU, based on Pentium core with MMX instruction set support.

'pentiumpro'
: Intel Pentium Pro CPU with no MMX support.

'i686'
: When used with `-march`, the Pentium Pro instruction set is used, so the code runs on all i686 family chips. When used with `-mtune`, it has the same meaning as 'generic'.

'pentium2'
: Intel Pentium II CPU, based on Pentium Pro core with MMX and FXSR instruction set support.

'pentium3'
'pentium3m'
: Intel Pentium III CPU, based on Pentium Pro core with MMX, FXSR and SSE instruction set support.

'pentium-m'
: Intel Pentium M; low-power version of Intel Pentium III CPU with MMX, SSE, SSE2 and FXSR instruction set support. Used by Centrino notebooks.

'pentium4'
'pentium4m'
: Intel Pentium 4 CPU with MMX, SSE, SSE2 and FXSR instruction set support.

'prescott'
: Improved version of Intel Pentium 4 CPU with MMX, SSE, SSE2, SSE3 and FXSR instruction set support.

'nocona'
: Improved version of Intel Pentium 4 CPU with 64-bit extensions, MMX, SSE, SSE2, SSE3 and FXSR instruction set support.

'core2'
: Intel Core 2 CPU with 64-bit extensions, MMX, SSE, SSE2, SSE3, SSSE3, CX16, SAHF and FXSR instruction set support.

'nehalem'
'corei7'
: Intel Nehalem CPU with 64-bit extensions, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF and FXSR instruction set support.

'westmere'
: Intel Westmere CPU with 64-bit extensions, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF, FXSR and PCLMUL instruction set support.

'sandybridge'
'corei7-avx'
Intel Sandy Bridge CPU with 64-bit extensions, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF, FXSR, AVX, XSAVE and PCLMUL instruction set support.

'ivybridge'
'core-avx-i'
Intel Ivy Bridge CPU with 64-bit extensions, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF, FXSR, AVX, XSAVE, PCLMUL, FSGSBASE, RDRND and F16C instruction set support.

'haswell'
'core-avx2'
Intel Haswell CPU with 64-bit extensions, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF, FXSR, AVX, XSAVE, PCLMUL, FSGSBASE, RDRND, F16C, AVX2, BMI, BMI2, LZCNT, FMA, MOVBE and HLE instruction set support.

'broadwell'
Intel Broadwell CPU with 64-bit extensions, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF, FXSR, AVX, XSAVE, PCLMUL, FSGSBASE, RDRND, F16C, AVX2, BMI, BMI2, LZCNT, FMA, MOVBE, HLE, RDSEED, ADCX and PREFETCHW instruction set support.

'skylake' Intel Skylake CPU with 64-bit extensions, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF, FXSR, AVX, XSAVE, PCLMUL, FSGSBASE, RDRND, F16C, AVX2, BMI, BMI2, LZCNT, FMA, MOVBE, HLE, RDSEED, ADCX, PREFETCHW, AES, CLFLUSHOPT, XSAVEC, XSAVES and SGX instruction set support.

'skylake-avx512'
Intel Skylake Server CPU with 64-bit extensions, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF, FXSR, AVX, XSAVE, PCLMUL, FSGSBASE, RDRND, F16C, AVX2, BMI, BMI2, LZCNT, FMA, MOVBE, HLE, RDSEED, ADCX, PREFETCHW, AES, CLFLUSHOPT, XSAVEC, XSAVES, SGX, AVX512F, CLWB, AVX512VL, AVX512BW, AVX512DQ and AVX512CD instruction set support.

'cascadelake'
Intel Cascade Lake CPU with 64-bit extensions, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF, FXSR, AVX, XSAVE, PCLMUL, FSGSBASE, RDRND, F16C, AVX2, BMI, BMI2, LZCNT, FMA, MOVBE, HLE, RDSEED, ADCX, PREFETCHW, AES, CLFLUSHOPT, XSAVEC, XSAVES,

SGX, AVX512F, CLWB, AVX512VL, AVX512BW, AVX512DQ, AVX512CD and AVX512VNNI instruction set support.

'cannonlake'
Intel Cannon Lake Server CPU with 64-bit extensions, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF, FXSR, AVX, XSAVE, PCLMUL, FSGSBASE, RDRND, F16C, AVX2, BMI, BMI2, LZCNT, FMA, MOVBE, HLE, RDSEED, ADCX, PREFETCHW, AES, CLFLUSHOPT, XSAVEC, XSAVES, SGX, AVX512F, AVX512VL, AVX512BW, AVX512DQ, AVX512CD, PKU, AVX512VBMI, AVX512IFMA and SHA instruction set support.

'cooperlake'
Intel Cooper Lake CPU with 64-bit extensions, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF, FXSR, AVX, XSAVE, PCLMUL, FSGSBASE, RDRND, F16C, AVX2, BMI, BMI2, LZCNT, FMA, MOVBE, HLE, RDSEED, ADCX, PREFETCHW, AES, CLFLUSHOPT, XSAVEC, XSAVES, SGX, AVX512F, CLWB, AVX512VL, AVX512BW, AVX512DQ, AVX512CD, AVX512VNNI and AVX512BF16 instruction set support.

'icelake-client'
Intel Ice Lake Client CPU with 64-bit extensions, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF, FXSR, AVX, XSAVE, PCLMUL, FSGSBASE, RDRND, F16C, AVX2, BMI, BMI2, LZCNT, FMA, MOVBE, HLE, RDSEED, ADCX, PREFETCHW, AES, CLFLUSHOPT, XSAVEC, XSAVES, SGX, AVX512F, AVX512VL, AVX512BW, AVX512DQ, AVX512CD, PKU, AVX512VBMI, AVX512IFMA, SHA, AVX512VNNI, GFNI, VAES, AVX512VBMI2 , VPCLMULQDQ, AVX512BITALG, RDPID and AVX512VPOPCNTDQ instruction set support.

'icelake-server'
Intel Ice Lake Server CPU with 64-bit extensions, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF, FXSR, AVX, XSAVE, PCLMUL, FSGSBASE, RDRND, F16C, AVX2, BMI, BMI2, LZCNT, FMA, MOVBE, HLE, RDSEED, ADCX, PREFETCHW, AES, CLFLUSHOPT, XSAVEC, XSAVES, SGX, AVX512F, AVX512VL, AVX512BW, AVX512DQ, AVX512CD, PKU, AVX512VBMI, AVX512IFMA, SHA, AVX512VNNI, GFNI, VAES, AVX512VBMI2 , VPCLMULQDQ, AVX512BITALG, RDPID, AVX512VPOPCNTDQ, PCONFIG, WBNOINVD and CLWB instruction set support.

'tigerlake'
Intel Tiger Lake CPU with 64-bit extensions, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF, FXSR,

AVX, XSAVE, PCLMUL, FSGSBASE, RDRND, F16C, AVX2, BMI, BMI2, LZCNT, FMA, MOVBE, HLE, RDSEED, ADCX, PREFETCHW, AES, CLFLUSHOPT, XSAVEC, XSAVES, SGX, AVX512F, AVX512VL, AVX512BW, AVX512DQ, AVX512CD PKU, AVX512VBMI, AVX512IFMA, SHA, AVX512VNNI, GFNI, VAES, AVX512VBMI2, VPCLMULQDQ, AVX512BITALG, RDPID, AVX512VPOPCNTDQ, MOVDIRI, MOVDIR64B, CLWB, AVX512VP2INTERSECT and KEYLOCKER instruction set support.

'rocketlake'
: Intel Rocket Lake CPU with 64-bit extensions, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF, FXSR, AVX, XSAVE, PCLMUL, FSGSBASE, RDRND, F16C, AVX2, BMI, BMI2, LZCNT, FMA, MOVBE, HLE, RDSEED, ADCX, PREFETCHW, AES, CLFLUSHOPT, XSAVEC, XSAVES, AVX512F, AVX512VL, AVX512BW, AVX512DQ, AVX512CD PKU, AVX512VBMI, AVX512IFMA, SHA, AVX512VNNI, GFNI, VAES, AVX512VBMI2, VPCLMULQDQ, AVX512BITALG, RDPID and AVX512VPOPCNTDQ instruction set support.

'alderlake'
'raptorlake'
'meteorlake'
'gracemont'
: Intel Alder Lake/Raptor Lake/Meteor Lake/Gracemont CPU with 64-bit extensions, MOVBE, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, AES, PREFETCHW, PCLMUL, RDRND, XSAVE, XSAVEC, XSAVES, XSAVEOPT, FSGSBASE, PTWRITE, RDPID, SGX, GFNI-SSE, CLWB, MOVDIRI, MOVDIR64B, WAITPKG, ADCX, AVX, AVX2, BMI, BMI2, F16C, FMA, LZCNT, PCONFIG, PKU, VAES, VPCLMULQDQ, SERIALIZE, HRESET, KL, WIDEKL and AVX-VNNI instruction set support.

'arrowlake'
: Intel Arrow Lake CPU with 64-bit extensions, MOVBE, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, AES, PREFETCHW, PCLMUL, RDRND, XSAVE, XSAVEC, XSAVES, XSAVEOPT, FSGSBASE, PTWRITE, RDPID, SGX, GFNI-SSE, CLWB, MOVDIRI, MOVDIR64B, WAITPKG, ADCX, AVX, AVX2, BMI, BMI2, F16C, FMA, LZCNT, PCONFIG, PKU, VAES, VPCLMULQDQ, SERIALIZE, HRESET, KL, WIDEKL, AVX-VNNI, UINTR, AVXIFMA, AVXVNNIINT8, AVXNECONVERT and CMPCCXADD instruction set support.

'arrowlake-s'
'lunarlake'
: Intel Arrow Lake S/Lunar Lake CPU with 64-bit extensions, MOVBE, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, AES, PREFETCHW, PCLMUL, RDRND, XSAVE, XSAVEC, XSAVES, XSAVEOPT, FSGSBASE, PTWRITE, RDPID, SGX, GFNI-SSE, CLWB, MOVDIRI, MOVDIR64B, WAITPKG, ADCX, AVX, AVX2, BMI, BMI2, F16C, FMA, LZCNT, PCONFIG, PKU, VAES, VPCLMULQDQ, SERIALIZE, HRESET, KL, WIDEKL, AVX-VNNI, UINTR, AVXIFMA, AVXVNNIINT8, AVXNECONVERT, CMPCCXADD, AVXVNNIINT16, SHA512, SM3 and SM4 instruction set support.

'pantherlake'
'wildcatlake'
: Intel Panther Lake/Wildcat Lake CPU with 64-bit extensions, MOVBE, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, AES, PREFETCHW, PCLMUL, RDRND, XSAVE, XSAVEC, XSAVES, XSAVEOPT, FSGSBASE, PTWRITE, RDPID, SGX, GFNI-SSE, CLWB, MOVDIRI, MOVDIR64B, WAITPKG, ADCX, AVX, AVX2, BMI, BMI2, F16C, FMA, LZCNT, PCONFIG, PKU, VAES, VPCLMULQDQ, SERIALIZE, HRESET, AVX-VNNI, UINTR, AVXIFMA, AVXVNNIINT8, AVXNECONVERT, CMPCCXADD, AVXVNNIINT16, SHA512, SM3 and SM4 instruction set support.

'novalake'
: Intel Nova Lake CPU with 64-bit extensions, MOVBE, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, AES, PREFETCHW, PCLMUL, RDRND, XSAVE, XSAVEC, XSAVES, XSAVEOPT, FSGSBASE, PTWRITE, RDPID, SGX, GFNI-SSE, CLWB, MOVDIRI, MOVDIR64B, WAITPKG, ADCX, AVX, AVX2, BMI, BMI2, F16C, FMA, LZCNT, PCONFIG, PKU, VAES, VPCLMULQDQ, SERIALIZE, HRESET, AVX-VNNI, UINTR, AVXIFMA, AVXVNNIINT8, AVXNECONVERT, CMPCCXADD, AVXVNNIINT16, SHA512, SM3, SM4, PREFETCHI, APX_F, AVX10.1, AVX10.2 and MOVRS instruction set support.

'sapphirerapids'
'emeraldrapids'
: Intel Sapphire Rapids/Emerald Rapids CPU with 64-bit extensions, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF, FXSR, AVX, XSAVE, PCLMUL, FSGSBASE, RDRND, F16C, AVX2, BMI, BMI2, LZCNT, FMA, MOVBE, HLE, RDSEED, ADCX, PREFETCHW, AES, CLFLUSHOPT, XSAVEC, XSAVES, SGX, AVX512F, AVX512VL, AVX512BW, AVX512DQ, AVX512CD, PKU, AVX512VBMI, AVX512IFMA, SHA, AVX512VNNI, GFNI,

VAES, AVX512VBMI2, VPCLMULQDQ, AVX512BITALG, RDPID, AVX512VPOPCNTDQ, PCONFIG, WBNOINVD, CLWB, MOVDIRI, MOVDIR64B, ENQCMD, CLDEMOTE, PTWRITE, WAITPKG, SERIALIZE, TSXLDTRK, UINTR, AMX-BF16, AMX-TILE, AMX-INT8, AVX-VNNI, AVX512-FP16 and AVX512BF16 instruction set support.

'`graniterapids`'
: Intel Granite Rapids CPU with 64-bit extensions, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF, FXSR, AVX, XSAVE, PCLMUL, FSGSBASE, RDRND, F16C, AVX2, BMI, BMI2, LZCNT, FMA, MOVBE, HLE, RDSEED, ADCX, PREFETCHW, AES, CLFLUSHOPT, XSAVEC, XSAVES, SGX, AVX512F, AVX512VL, AVX512BW, AVX512DQ, AVX512CD, PKU, AVX512VBMI, AVX512IFMA, SHA, AVX512VNNI, GFNI, VAES, AVX512VBMI2, VPCLMULQDQ, AVX512BITALG, RDPID, AVX512VPOPCNTDQ, PCONFIG, WBNOINVD, CLWB, MOVDIRI, MOVDIR64B, ENQCMD, CLDEMOTE, PTWRITE, WAITPKG, SERIALIZE, TSXLDTRK, UINTR, AMX-BF16, AMX-TILE, AMX-INT8, AVX-VNNI, AVX512-FP16, AVX512BF16, AMX-FP16 and PREFETCHI instruction set support.

'`graniterapids-d`'
: Intel Granite Rapids D CPU with 64-bit extensions, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF, FXSR, AVX, XSAVE, PCLMUL, FSGSBASE, RDRND, F16C, AVX2, BMI, BMI2, LZCNT, FMA, MOVBE, HLE, RDSEED, ADCX, PREFETCHW, AES, CLFLUSHOPT, XSAVEC, XSAVES, SGX, AVX512F, AVX512VL, AVX512BW, AVX512DQ, AVX512CD, PKU, AVX512VBMI, AVX512IFMA, SHA, AVX512VNNI, GFNI, VAES, AVX512VBMI2, VPCLMULQDQ, AVX512BITALG, RDPID, AVX512VPOPCNTDQ, PCONFIG, WBNOINVD, CLWB, MOVDIRI, MOVDIR64B, ENQCMD, CLDEMOTE, PTWRITE, WAITPKG, SERIALIZE, TSXLDTRK, UINTR, AMX-BF16, AMX-TILE, AMX-INT8, AVX-VNNI, AVX512FP16, AVX512BF16, AMX-FP16, PREFETCHI and AMX-COMPLEX instruction set support.

'`diamondrapids`'
: Intel Diamond Rapids CPU with 64-bit extensions, MOVBE, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF, FXSR, AVX, XSAVE, PCLMUL, FSGSBASE, RDRND, F16C, AVX2, BMI, BMI2, LZCNT, FMA, MOVBE, HLE, RDSEED, ADCX, PREFETCHW, AES, CLFLUSHOPT, XSAVEC, XSAVES, SGX, AVX512F, AVX512VL, AVX512BW, AVX512DQ, AVX512CD, PKU, AVX512VBMI, AVX512IFMA, SHA, AVX512VNNI, GFNI, VAES, AVX512VBMI2, VPCLMULQDQ, AVX512BITALG, RDPID, AVX512VPOPCNTDQ,

PCONFIG, WBNOINVD, CLWB, MOVDIRI, MOVDIR64B, ENQCMD, CLDEMOTE, PTWRITE, WAITPKG, SERIALIZE, TSXLDTRK, UINTR, AMX-BF16, AMX-TILE, AMX-INT8, AVX-VNNI, AVX512FP16, AVX512BF16, AMX-FP16, PREFETCHI, AMX-COMPLEX, AVX10.1-512, AVX-IFMA, AVX-NE-CONVERT, AVX-VNNI-INT16, AVX-VNNI-INT8, CMPccXADD, SHA512, SM3, SM4, AVX10.2-512, APX_F, AMX-AVX512, AMX-FP8, AMX-TF32, MOVRS and AMX-MOVRS instruction set support.

'bonnell'
'atom' Intel Bonnell CPU with 64-bit extensions, MOVBE, MMX, SSE, SSE2, SSE3 and SSSE3 instruction set support.

'silvermont'
'slm' Intel Silvermont CPU with 64-bit extensions, MOVBE, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF, FXSR, PCLMUL, PREFETCHW and RDRND instruction set support.

'goldmont'
Intel Goldmont CPU with 64-bit extensions, MOVBE, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF, FXSR, PCLMUL, PREFETCHW, RDRND, AES, SHA, RDSEED, XSAVE, XSAVEC, XSAVES, XSAVEOPT, CLFLUSHOPT and FSGSBASE instruction set support.

'goldmont-plus'
Intel Goldmont Plus CPU with 64-bit extensions, MOVBE, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF, FXSR, PCLMUL, PREFETCHW, RDRND, AES, SHA, RDSEED, XSAVE, XSAVEC, XSAVES, XSAVEOPT, CLFLUSHOPT, FSGSBASE, PTWRITE, RDPID and SGX instruction set support.

'tremont' Intel Tremont CPU with 64-bit extensions, MOVBE, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, CX16, SAHF, FXSR, PCLMUL, PREFETCHW, RDRND, AES, SHA, RDSEED, XSAVE, XSAVEC, XSAVES, XSAVEOPT, CLFLUSHOPT, FSGSBASE, PTWRITE, RDPID, SGX, CLWB, GFNI-SSE, MOVDIRI, MOVDIR64B, CLDEMOTE and WAITPKG instruction set support.

'sierraforest'
Intel Sierra Forest CPU with 64-bit extensions, MOVBE, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, AES, PREFETCHW, PCLMUL, RDRND, XSAVE, XSAVEC, XSAVES, XSAVEOPT, FSGSBASE, PTWRITE, RDPID, SGX, GFNI-SSE, CLWB, MOVDIRI, MOVDIR64B, CLDEMOTE, WAITPKG, ADCX, AVX, AVX2, BMI, BMI2, F16C, FMA,

LZCNT, PCONFIG, PKU, VAES, VPCLMULQDQ, SERIALIZE, HRESET, KL, WIDEKL, AVX-VNNI, AVXIFMA, AVXVNNIINT8, AVXNECONVERT, CMPCCXADD, ENQCMD and UINTR instruction set support.

'grandridge'
: Intel Grand Ridge CPU with 64-bit extensions, MOVBE, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, AES, PREFETCHW, PCLMUL, RDRND, XSAVE, XSAVEC, XSAVES, XSAVEOPT, FSGSBASE, PTWRITE, RDPID, SGX, GFNI-SSE, CLWB, MOVDIRI, MOVDIR64B, CLDEMOTE, WAITPKG, ADCX, AVX, AVX2, BMI, BMI2, F16C, FMA, LZCNT, PCONFIG, PKU, VAES, VPCLMULQDQ, SERIALIZE, HRESET, KL, WIDEKL, AVX-VNNI, AVXIFMA, AVXVNNIINT8, AVXNECONVERT, CMPCCXADD, ENQCMD and UINTR instruction set support.

'clearwaterforest'
: Intel Clearwater Forest CPU with 64-bit extensions, MOVBE, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, AES, PREFETCHW, PCLMUL, RDRND, XSAVE, XSAVEC, XSAVES, XSAVEOPT, FSGSBASE, PTWRITE, RDPID, SGX, GFNI-SSE, CLWB, MOVDIRI, MOVDIR64B, CLDEMOTE, WAITPKG, ADCX, AVX, AVX2, BMI, BMI2, F16C, FMA, LZCNT, PCONFIG, PKU, VAES, VPCLMULQDQ, SERIALIZE, HRESET, AVX-VNNI, ENQCMD, UINTR, AVXIFMA, AVXVNNIINT8, AVXNECONVERT, CMPCCXADD, AVXVNNIINT16, SHA512, SM3, SM4, USER_MSR and PREFETCHI instruction set support.

'k6'
: AMD K6 CPU with MMX instruction set support.

'k6-2'
'k6-3'
: Improved versions of AMD K6 CPU with MMX and 3DNow! instruction set support.

'athlon'
'athlon-tbird'
: AMD Athlon CPU with MMX, 3dNOW!, enhanced 3DNow! and SSE prefetch instructions support.

'athlon-4'
'athlon-xp'
'athlon-mp'
: Improved AMD Athlon CPU with MMX, 3DNow!, enhanced 3DNow! and full SSE instruction set support.

'k8'
'opteron'
'athlon64'
'athlon-fx'
: Processors based on the AMD K8 core with x86-64 instruction set support, including the AMD Opteron, Athlon 64, and Athlon 64 FX processors. (This supersets MMX, SSE, SSE2, 3DNow!, enhanced 3DNow! and 64-bit instruction set extensions.)

'k8-sse3'
'opteron-sse3'
'athlon64-sse3'
: Improved versions of AMD K8 cores with SSE3 instruction set support.

'amdfam10'
'barcelona'
: CPUs based on AMD Family 10h cores with x86-64 instruction set support. (This supersets MMX, SSE, SSE2, SSE3, SSE4A, 3DNow!, enhanced 3DNow!, ABM and 64-bit instruction set extensions.)

'bdver1'
: CPUs based on AMD Family 15h cores with x86-64 instruction set support. (This supersets FMA4, AVX, XOP, LWP, AES, PCLMUL, CX16, MMX, SSE, SSE2, SSE3, SSE4A, SSSE3, SSE4.1, SSE4.2, ABM and 64-bit instruction set extensions.)

'bdver2'
: AMD Family 15h core based CPUs with x86-64 instruction set support. (This supersets BMI, TBM, F16C, FMA, FMA4, AVX, XOP, LWP, AES, PCLMUL, CX16, MMX, SSE, SSE2, SSE3, SSE4A, SSSE3, SSE4.1, SSE4.2, ABM and 64-bit instruction set extensions.)

'bdver3'
: AMD Family 15h core based CPUs with x86-64 instruction set support. (This supersets BMI, TBM, F16C, FMA, FMA4, FSGSBASE, AVX, XOP, LWP, AES, PCLMUL, CX16, MMX, SSE, SSE2, SSE3, SSE4A, SSSE3, SSE4.1, SSE4.2, ABM and 64-bit instruction set extensions.)

'bdver4'
: AMD Family 15h core based CPUs with x86-64 instruction set support. (This supersets BMI, BMI2, TBM, F16C, FMA, FMA4, FSGSBASE, AVX, AVX2, XOP, LWP, AES, PCLMUL, CX16, MOVBE, MMX, SSE, SSE2, SSE3, SSE4A, SSSE3, SSE4.1, SSE4.2, ABM and 64-bit instruction set extensions.)

'znver1'
: AMD Family 17h core based CPUs with x86-64 instruction set support. (This supersets BMI, BMI2, F16C, FMA, FSGSBASE, AVX, AVX2, ADCX, RDSEED, MWAITX, SHA, CLZERO, AES, PCLMUL, CX16, MOVBE, MMX, SSE, SSE2, SSE3, SSE4A, SSSE3, SSE4.1, SSE4.2, ABM, XSAVEC, XSAVES, CLFLUSHOPT, POPCNT, and 64-bit instruction set extensions.)

'znver2' AMD Family 17h core based CPUs with x86-64 instruction set support. (This supersets BMI, BMI2, CLWB, F16C, FMA, FSGSBASE, AVX, AVX2, ADCX, RDSEED, MWAITX, SHA, CLZERO, AES, PCLMUL, CX16, MOVBE, MMX, SSE, SSE2, SSE3, SSE4A, SSSE3, SSE4.1, SSE4.2, ABM, XSAVEC, XSAVES, CLFLUSHOPT, POPCNT, RDPID, WBNOINVD, and 64-bit instruction set extensions.)

'znver3' AMD Family 19h core based CPUs with x86-64 instruction set support. (This supersets BMI, BMI2, CLWB, F16C, FMA, FSGSBASE, AVX, AVX2, ADCX, RDSEED, MWAITX, SHA, CLZERO, AES, PCLMUL, CX16, MOVBE, MMX, SSE, SSE2, SSE3, SSE4A, SSSE3, SSE4.1, SSE4.2, ABM, XSAVEC, XSAVES, CLFLUSHOPT, POPCNT, RDPID, WBNOINVD, PKU, VPCLMULQDQ, VAES, and 64-bit instruction set extensions.)

'znver4' AMD Family 19h core based CPUs with x86-64 instruction set support. (This supersets BMI, BMI2, CLWB, F16C, FMA, FSGSBASE, AVX, AVX2, ADCX, RDSEED, MWAITX, SHA, CLZERO, AES, PCLMUL, CX16, MOVBE, MMX, SSE, SSE2, SSE3, SSE4A, SSSE3, SSE4.1, SSE4.2, ABM, XSAVEC, XSAVES, CLFLUSHOPT, POPCNT, RDPID, WBNOINVD, PKU, VPCLMULQDQ, VAES, AVX512F, AVX512DQ, AVX512IFMA, AVX512CD, AVX512BW, AVX512VL, AVX512BF16, AVX512VBMI, AVX512VBMI2, AVX512VNNI, AVX512BITALG, AVX512VPOPCNTDQ, GFNI and 64-bit instruction set extensions.)

'znver5' AMD Family 1ah core based CPUs with x86-64 instruction set support. (This supersets BMI, BMI2, CLWB, F16C, FMA, FSGSBASE, AVX, AVX2, ADCX, RDSEED, MWAITX, SHA, CLZERO, AES, PCLMUL, CX16, MOVBE, MMX, SSE, SSE2, SSE3, SSE4A, SSSE3, SSE4.1, SSE4.2, ABM, XSAVEC, XSAVES, CLFLUSHOPT, POPCNT, RDPID, WBNOINVD, PKU, VPCLMULQDQ, VAES, AVX512F, AVX512DQ, AVX512IFMA, AVX512CD, AVX512BW, AVX512VL, AVX512BF16, AVX512VBMI, AVX512VBMI2, AVX512VNNI, AVX512BITALG, AVX512VPOPCNTDQ, GFNI, AVXVNNI, MOVDIRI, MOVDIR64B, AVX512VP2INTERSECT, PREFETCHI and 64-bit instruction set extensions.)

'btver1' CPUs based on AMD Family 14h cores with x86-64 instruction set support. (This supersets MMX, SSE, SSE2, SSE3, SSSE3, SSE4A, CX16, ABM and 64-bit instruction set extensions.)

'btver2' CPUs based on AMD Family 16h cores with x86-64 instruction set support. This includes MOVBE, F16C, BMI, AVX, PCLMUL, AES, SSE4.2, SSE4.1, CX16, ABM, SSE4A, SSSE3, SSE3, SSE2, SSE, MMX and 64-bit instruction set extensions.

'winchip-c6'
: IDT WinChip C6 CPU, dealt in same way as i486 with additional MMX instruction set support.

'winchip2'
: IDT WinChip 2 CPU, dealt in same way as i486 with additional MMX and 3DNow! instruction set support.

'c3'
: VIA C3 CPU with MMX and 3DNow! instruction set support. (No scheduling is implemented for this chip.)

'c3-2'
: VIA C3-2 (Nehemiah/C5XL) CPU with MMX and SSE instruction set support. (No scheduling is implemented for this chip.)

'c7'
: VIA C7 (Esther) CPU with MMX, SSE, SSE2 and SSE3 instruction set support. (No scheduling is implemented for this chip.)

'samuel-2'
: VIA Eden Samuel 2 CPU with MMX and 3DNow! instruction set support. (No scheduling is implemented for this chip.)

'nehemiah'
: VIA Eden Nehemiah CPU with MMX and SSE instruction set support. (No scheduling is implemented for this chip.)

'esther'
: VIA Eden Esther CPU with MMX, SSE, SSE2 and SSE3 instruction set support. (No scheduling is implemented for this chip.)

'eden-x2'
: VIA Eden X2 CPU with x86-64, MMX, SSE, SSE2 and SSE3 instruction set support. (No scheduling is implemented for this chip.)

'eden-x4'
: VIA Eden X4 CPU with x86-64, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, AVX and AVX2 instruction set support. (No scheduling is implemented for this chip.)

'nano'
: Generic VIA Nano CPU with x86-64, MMX, SSE, SSE2, SSE3 and SSSE3 instruction set support. (No scheduling is implemented for this chip.)

'nano-1000'
: VIA Nano 1xxx CPU with x86-64, MMX, SSE, SSE2, SSE3 and SSSE3 instruction set support. (No scheduling is implemented for this chip.)

'nano-2000'
: VIA Nano 2xxx CPU with x86-64, MMX, SSE, SSE2, SSE3 and SSSE3 instruction set support. (No scheduling is implemented for this chip.)

'nano-3000'
: VIA Nano 3xxx CPU with x86-64, MMX, SSE, SSE2, SSE3, SSSE3 and SSE4.1 instruction set support. (No scheduling is implemented for this chip.)

'nano-x2' VIA Nano Dual Core CPU with x86-64, MMX, SSE, SSE2, SSE3, SSSE3 and SSE4.1 instruction set support. (No scheduling is implemented for this chip.)

'nano-x4' VIA Nano Quad Core CPU with x86-64, MMX, SSE, SSE2, SSE3, SSSE3 and SSE4.1 instruction set support. (No scheduling is implemented for this chip.)

'lujiazui'
: ZHAOXIN lujiazui CPU with x86-64, MOVBE, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, POPCNT, AES, PCLMUL, RDRND, XSAVE, XSAVEOPT, FSGSBASE, CX16, ABM, BMI, BMI2, FXSR, RDSEED instruction set support. While the CPUs do support AVX and F16C, these aren't enabled by `-march=lujiazui` for performance reasons.

'yongfeng'
: ZHAOXIN yongfeng CPU with x86-64, MOVBE, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, AVX, POPCNT, AES, PCLMUL, RDRND, XSAVE, XSAVEOPT, FSGSBASE, CX16, ABM, BMI, BMI2, F16C, FXSR, RDSEED, AVX2, FMA, SHA, LZCNT instruction set support.

'shijidadao'
: ZHAOXIN shijidadao CPU with x86-64, MOVBE, MMX, SSE, SSE2, SSE3, SSSE3, SSE4.1, SSE4.2, AVX, POPCNT, AES, PCLMUL, RDRND, XSAVE, XSAVEOPT, FSGSBASE, CX16, ABM, BMI, BMI2, F16C, FXSR, RDSEED, AVX2, FMA, SHA, LZCNT instruction set support.

'geode' AMD Geode embedded processor with MMX and 3DNow! instruction set support.

`-mtune=`*`cpu-type`*
: Tune to *cpu-type* everything applicable about the generated code, except for the ABI and the set of available instructions. While picking a specific *cpu-type* schedules things appropriately for that particular chip, the compiler does not generate any code that cannot run on the default machine type unless you use a `-march=`*`cpu-type`* option. For example, if GCC is configured for i686-pc-linux-gnu then `-mtune=pentium4` generates code that is tuned for Pentium 4 but still runs on i686 machines.

The choices for *cpu-type* are the same as for `-march`. In addition, `-mtune` supports 2 extra choices for *cpu-type*:

'generic' Produce code optimized for the most common IA32/AMD64/EM64T processors. If you know the CPU on which your code will run, then you should use the corresponding `-mtune` or `-march` option instead of `-mtune=generic`. But, if you do not know exactly what CPU users of your application will have, then you should use this option.

As new processors are deployed in the marketplace, the behavior of this option will change. Therefore, if you upgrade to a newer version of GCC, code generation controlled by this option will change to reflect the processors that are most common at the time that version of GCC is released.

There is no `-march=generic` option because `-march` indicates the instruction set the compiler can use, and there is no generic instruction set applicable to all processors. In contrast, `-mtune` indicates the processor (or, in this case, collection of processors) for which the code is optimized.

'`intel`' Produce code optimized for the most current Intel processors, which are Haswell and Silvermont for this version of GCC. If you know the CPU on which your code will run, then you should use the corresponding `-mtune` or `-march` option instead of `-mtune=intel`. But, if you want your application performs better on both Diamond Rapids and Clearwater Forest, then you should use this option.

As new Intel processors are deployed in the marketplace, the behavior of this option will change. Therefore, if you upgrade to a newer version of GCC, code generation controlled by this option will change to reflect the most current Intel processors at the time that version of GCC is released.

There is no `-march=intel` option because `-march` indicates the instruction set the compiler can use, and there is no common instruction set applicable to all processors. In contrast, `-mtune` indicates the processor (or, in this case, collection of processors) for which the code is optimized.

`-mcpu=`*`cpu-type`*

A deprecated synonym for `-mtune`.

`-mfpmath=`*`unit`*

Generate floating-point arithmetic for selected unit *unit*. The choices for *unit* are:

'`387`' Use the standard 387 floating-point coprocessor present on the majority of chips and emulated otherwise. Code compiled with this option runs almost everywhere. The temporary results are computed in 80-bit precision instead of the precision specified by the type, resulting in slightly different results compared to most of other chips. See `-ffloat-store` for more detailed description.

This is the default choice for non-Darwin x86-32 targets.

'`sse`' Use scalar floating-point instructions present in the SSE instruction set. This instruction set is supported by Pentium III and newer chips, and in the AMD line by Athlon-4, Athlon XP and Athlon MP chips. The earlier version of the SSE instruction set supports only single-precision arithmetic, thus the double and extended-precision arithmetic are still done using 387. A later version, present only in Pentium 4 and AMD x86-64 chips, supports double-precision arithmetic too.

For the x86-32 compiler, you must use `-march=cpu-type`, `-msse` or `-msse2` switches to enable SSE extensions and make this option effective. For the x86-64 compiler, these extensions are enabled by default.

The resulting code should be considerably faster in the majority of cases and avoid the numerical instability problems of 387 code, but may break some existing code that expects temporaries to be 80 bits.

This is the default choice for the x86-64 compiler, Darwin x86-32 targets, and the default choice for x86-32 targets with the SSE2 instruction set when `-ffast-math` is enabled.

'`sse,387`'
'`sse+387`'
'`both`' Attempt to utilize both instruction sets at once. This effectively doubles the amount of available registers, and on chips with separate execution units for 387 and SSE the execution resources too. Use this option with care, as it is still experimental, because the GCC register allocator does not model separate functional units well, resulting in unstable performance.

`-masm=dialect`
Output assembly instructions using selected *dialect*. Also affects which dialect is used for basic `asm` (see Section 6.11.1 [Basic Asm], page 753) and extended `asm` (see Section 6.11.2 [Extended Asm], page 754). Supported choices (in dialect order) are '`att`' or '`intel`'. The default is '`att`'. Darwin does not support '`intel`'.

`-mieee-fp`
`-mno-ieee-fp`
Control whether or not the compiler uses IEEE floating-point comparisons. These correctly handle the case where the result of a comparison is unordered.

`-m80387`
`-mhard-float`
Generate output containing 80387 instructions for floating point.

`-mno-80387`
`-msoft-float`
Generate output containing library calls for floating point.

Warning: the requisite libraries are not part of GCC. Normally the facilities of the machine's usual C compiler are used, but this cannot be done directly in cross-compilation. You must make your own arrangements to provide suitable library functions for cross-compilation.

On machines where a function returns floating-point results in the 80387 register stack, some floating-point opcodes may be emitted even if `-msoft-float` is used.

`-mno-fp-ret-in-387`

Do not use the FPU registers for return values of functions.

The usual calling convention has functions return values of types `float` and `double` in an FPU register, even if there is no FPU. The idea is that the operating system should emulate an FPU.

The option `-mno-fp-ret-in-387` causes such values to be returned in ordinary CPU registers instead.

`-mno-fancy-math-387`

Some 387 emulators do not support the `sin`, `cos` and `sqrt` instructions for the 387. Specify this option to avoid generating those instructions. This option is overridden when `-march` indicates that the target CPU always has an FPU and so the instruction does not need emulation. These instructions are not generated unless you also use the `-funsafe-math-optimizations` switch.

`-malign-double`
`-mno-align-double`

Control whether GCC aligns `double`, `long double`, and `long long` variables on a two-word boundary or a one-word boundary. Aligning `double` variables on a two-word boundary produces code that runs somewhat faster on a Pentium at the expense of more memory.

On x86-64, `-malign-double` is enabled by default.

Warning: if you use the `-malign-double` switch, structures containing the above types are aligned differently than the published application binary interface specifications for the x86-32 and are not binary compatible with structures in code compiled without that switch.

`-m96bit-long-double`
`-m128bit-long-double`

These switches control the size of `long double` type. The x86-32 application binary interface specifies the size to be 96 bits, so `-m96bit-long-double` is the default in 32-bit mode.

Modern architectures (Pentium and newer) prefer `long double` to be aligned to an 8- or 16-byte boundary. In arrays or structures conforming to the ABI, this is not possible. So specifying `-m128bit-long-double` aligns `long double` to a 16-byte boundary by padding the `long double` with an additional 32-bit zero.

In the x86-64 compiler, `-m128bit-long-double` is the default choice as its ABI specifies that `long double` is aligned on 16-byte boundary.

Notice that neither of these options enable any extra precision over the x87 standard of 80 bits for a `long double`.

Warning: if you override the default value for your target ABI, this changes the size of structures and arrays containing `long double` variables, as well as modifying the function calling convention for functions taking `long double`. Hence they are not binary-compatible with code compiled without that switch.

`-mlong-double-64`
`-mlong-double-80`
`-mlong-double-128`

These switches control the size of `long double` type. A size of 64 bits makes the `long double` type equivalent to the `double` type. This is the default for 32-bit Bionic C library. A size of 128 bits makes the `long double` type equivalent to the `__float128` type. This is the default for 64-bit Bionic C library.

Warning: if you override the default value for your target ABI, this changes the size of structures and arrays containing `long double` variables, as well as modifying the function calling convention for functions taking `long double`. Hence they are not binary-compatible with code compiled without that switch.

`-malign-data=`*`type`*

Control how GCC aligns variables. Supported values for *type* are '`compat`' uses increased alignment value compatible uses GCC 4.8 and earlier, '`abi`' uses alignment value as specified by the psABI, and '`cacheline`' uses increased alignment value to match the cache line size. '`compat`' is the default.

`-mlarge-data-threshold=`*`threshold`*

When `-mcmodel=medium` or `-mcmodel=large` is specified, data objects larger than *threshold* are placed in large data sections. The default is 65535.

`-mrtd` Use a different function-calling convention, in which functions that take a fixed number of arguments return with the `ret` *`num`* instruction, which pops their arguments while returning. This saves one instruction in the caller since there is no need to pop the arguments there.

You can specify that an individual function is called with this calling sequence with the function attribute `stdcall`. You can also override the `-mrtd` option by using the function attribute `cdecl`. See Section 6.4.1 [Function Attributes], page 621.

Warning: this calling convention is incompatible with the one normally used on Unix, so you cannot use it if you need to call libraries compiled with the Unix compiler.

Also, you must provide function prototypes for all functions that take variable numbers of arguments (including `printf`); otherwise incorrect code is generated for calls to those functions.

In addition, seriously incorrect code results if you call a function with too many arguments. (Normally, extra arguments are harmlessly ignored.)

`-mregparm=`*`num`*

Control how many registers are used to pass integer arguments. By default, no registers are used to pass arguments, and at most 3 registers can be used. You can control this behavior for a specific function by using the function attribute `regparm`. See Section 6.4.1 [Function Attributes], page 621.

Warning: if you use this switch, and *num* is nonzero, then you must build all modules with the same value, including any libraries. This includes the system libraries and startup modules.

`-msseregparm`

Use SSE register passing conventions for float and double arguments and return values. You can control this behavior for a specific function by using the function attribute `sseregparm`. See Section 6.4.1 [Function Attributes], page 621.

Warning: if you use this switch then you must build all modules with the same value, including any libraries. This includes the system libraries and startup modules.

`-mvect8-ret-in-mem`

Return 8-byte vectors in memory instead of MMX registers. This is the default on VxWorks to match the ABI of the Sun Studio compilers until version 12. *Only* use this option if you need to remain compatible with existing code produced by those previous compiler versions or older versions of GCC.

`-mpc32`
`-mpc64`
`-mpc80`

Set 80387 floating-point precision to 32, 64 or 80 bits. When `-mpc32` is specified, the significands of results of floating-point operations are rounded to 24 bits (single precision); `-mpc64` rounds the significands of results of floating-point operations to 53 bits (double precision) and `-mpc80` rounds the significands of results of floating-point operations to 64 bits (extended double precision), which is the default. When this option is used, floating-point operations in higher precisions are not available to the programmer without setting the FPU control word explicitly.

Setting the rounding of floating-point operations to less than the default 80 bits can speed some programs by 2% or more. Note that some mathematical libraries assume that extended-precision (80-bit) floating-point operations are enabled by default; routines in such libraries could suffer significant loss of accuracy, typically through so-called "catastrophic cancellation", when this option is used to set the precision to less than extended precision.

`-mdaz-ftz`

The flush-to-zero (FTZ) and denormals-are-zero (DAZ) flags in the MXCSR register are used to control floating-point calculations.SSE and AVX instructions including scalar and vector instructions could benefit from enabling the FTZ and DAZ flags when `-mdaz-ftz` is specified. Don't set FTZ/DAZ flags when `-mno-daz-ftz` or `-shared` is specified, `-mdaz-ftz` will set FTZ/DAZ flags even with `-shared`.

`-mstackrealign`

Realign the stack at entry. On the x86, the `-mstackrealign` option generates an alternate prologue and epilogue that realigns the run-time stack if necessary. This supports mixing legacy codes that keep 4-byte stack alignment with modern codes that keep 16-byte stack alignment for SSE compatibility. See also the attribute `force_align_arg_pointer`, applicable to individual functions.

`-mpreferred-stack-boundary=`*num*

Attempt to keep the stack boundary aligned to a 2 raised to *num* byte boundary. If `-mpreferred-stack-boundary` is not specified, the default is 4 (16 bytes or 128 bits).

Warning: When generating code for the x86-64 architecture with SSE extensions disabled, `-mpreferred-stack-boundary=3` can be used to keep the stack boundary aligned to 8 byte boundary. Since x86-64 ABI require 16 byte stack alignment, this is ABI incompatible and intended to be used in controlled environment where stack space is important limitation. This option leads to wrong code when functions compiled with 16 byte stack alignment (such as functions from a standard library) are called with misaligned stack. In this case, SSE instructions may lead to misaligned memory access traps. In addition, variable arguments are handled incorrectly for 16 byte aligned objects (including x87 long double and __int128), leading to wrong results. You must build all modules with `-mpreferred-stack-boundary=3`, including any libraries. This includes the system libraries and startup modules.

`-mincoming-stack-boundary=`*num*

Assume the incoming stack is aligned to a 2 raised to *num* byte boundary. If `-mincoming-stack-boundary` is not specified, the one specified by `-mpreferred-stack-boundary` is used.

On Pentium and Pentium Pro, `double` and `long double` values should be aligned to an 8-byte boundary (see `-malign-double`) or suffer significant run time performance penalties. On Pentium III, the Streaming SIMD Extension (SSE) data type `__m128` may not work properly if it is not 16-byte aligned.

To ensure proper alignment of this values on the stack, the stack boundary must be as aligned as that required by any value stored on the stack. Further, every function must be generated such that it keeps the stack aligned. Thus calling a function compiled with a higher preferred stack boundary from a function compiled with a lower preferred stack boundary most likely misaligns the stack. It is recommended that libraries that use callbacks always use the default setting.

This extra alignment does consume extra stack space, and generally increases code size. Code that is sensitive to stack space usage, such as embedded systems and operating system kernels, may want to reduce the preferred alignment to `-mpreferred-stack-boundary=2`.

`-mmmx`
`-msse`
`-msse2`
`-msse3`
`-mssse3`
`-msse4`
`-msse4a`
`-msse4.1`
`-msse4.2`
`-mavx`

-mavx2
-mavx512f
-mavx512cd
-mavx512vl
-mavx512bw
-mavx512dq
-mavx512ifma
-mavx512vbmi
-msha
-maes
-mpclmul
-mclflushopt
-mclwb
-mfsgsbase
-mptwrite
-mrdrnd
-mf16c
-mfma
-mpconfig
-mwbnoinvd
-mfma4
-mprfchw
-mrdpid
-mrdseed
-msgx
-mxop
-mlwp
-m3dnow
-m3dnowa
-mpopcnt
-mabm
-madx
-mbmi
-mbmi2
-mlzcnt
-mfxsr
-mxsave
-mxsaveopt
-mxsavec
-mxsaves
-mrtm
-mhle
-mtbm
-mmwaitx
-mclzero
-mpku

-mavx512vbmi2
-mavx512bf16
-mavx512fp16
-mgfni
-mvaes
-mwaitpkg
-mvpclmulqdq
-mavx512bitalg
-mmovdiri
-mmovdir64b
-menqcmd
-muintr
-mtsxldtrk
-mavx512vpopcntdq
-mavx512vp2intersect
-mavx512vnni
-mavxvnni
-mcldemote
-mserialize
-mamx-tile
-mamx-int8
-mamx-bf16
-mhreset
-mkl
-mwidekl
-mavxifma
-mavxvnniint8
-mavxneconvert
-mcmpccxadd
-mamx-fp16
-mprefetchi
-mraoint
-mamx-complex
-mavxvnniint16
-msm3
-msha512
-msm4
-mapxf
-musermsr
-mavx10.1
-mavx10.2
-mamx-avx512
-mamx-tf32
-mamx-fp8
-mmovrs

`-mamx-movrs`

These switches enable the use of instructions in the MMX, SSE, AVX512CD, AVX512VL, AVX512BW, AVX512DQ, AVX512IFMA, AVX512VBMI, SHA, AES, PCLMUL, CLFLUSHOPT, CLWB, FSGSBASE, PTWRITE, RDRND, F16C, FMA, PCONFIG, WBNOINVD, FMA4, PREFETCHW, RDPID, RDSEED, SGX, XOP, LWP, 3DNow!, enhanced 3DNow!, POPCNT, ABM, ADX, BMI, BMI2, LZCNT, FXSR, XSAVE, XSAVEOPT, XSAVEC, XSAVES, RTM, HLE, TBM, MWAITX, CLZERO, PKU, AVX512VBMI2, GFNI, VAES, WAITPKG, VPCLMULQDQ, AVX512BITALG, MOVDIRI, MOVDIR64B, AVX512BF16, ENQCMD, AVX512VPOPCNTDQ, AVX512VNNI, SERIALIZE, UINTR, HRESET, AMXTILE, AMXINT8, AMXBF16, KL, WIDEKL, AVXVNNI, AVX512-FP16, AVXIFMA, AVXVNNIINT8, AVXNECONVERT, CMPCCXADD, AMX-FP16, PREFETCHI, RAOINT, AMX-COMPLEX, AVXVNNIINT16, SM3, SHA512, SM4, APX_F, USER_MSR, AVX10.1, AVX10.2, AMX-AVX512, AMX-TF32, AMX-FP8, MOVRS, AMX-MOVRS or CLDEMOTE extended instruction sets. Each has a corresponding `-mno-` option to disable use of these instructions.

These extensions are also available as built-in functions: see Section 7.13.37 [x86 Built-in Functions], page 1031, for details of the functions enabled and disabled by these switches.

Note that `-msse4` enables both SSE4.1 and SSE4.2 support, while `-mno-sse4` turns off those features; neither form of the option affects SSE4A support, controlled separately by `-msse4a`.

To generate SSE/SSE2 instructions automatically from floating-point code (as opposed to 387 instructions), see `-mfpmath=sse`.

GCC depresses SSEx instructions when `-mavx` is used. Instead, it generates new AVX instructions or AVX equivalence for all SSEx instructions when needed.

These options enable GCC to use these extended instructions in generated code, even without `-mfpmath=sse`. Applications that perform run-time CPU detection must compile separate files for each supported architecture, using the appropriate flags. In particular, the file containing the CPU detection code should be compiled without these options.

`-mdump-tune-features`

This option instructs GCC to dump the names of the x86 performance tuning features and default settings. The names can be used in `-mtune-ctrl=`*`feature-list`*.

`-mtune-ctrl=`*`feature-list`*

This option is used to do fine grain control of x86 code generation features. *feature-list* is a comma separated list of *feature* names. See also `-mdump-tune-features`. When specified, the *feature* is turned on if it is not preceded with '`^`', otherwise, it is turned off. `-mtune-ctrl=`*`feature-list`* is intended to be used by GCC developers. Using it may lead to code paths not covered by testing and can potentially result in compiler ICEs or runtime errors.

`-mno-default`
: This option instructs GCC to turn off all tunable features. See also `-mtune-ctrl=`*`feature-list`* and `-mdump-tune-features`.

`-mcld`
: This option instructs GCC to emit a `cld` instruction in the prologue of functions that use string instructions. String instructions depend on the DF flag to select between autoincrement or autodecrement mode. While the ABI specifies the DF flag to be cleared on function entry, some operating systems violate this specification by not clearing the DF flag in their exception dispatchers. The exception handler can be invoked with the DF flag set, which leads to wrong direction mode when string instructions are used. This option can be enabled by default on 32-bit x86 targets by configuring GCC with the `--enable-cld` configure option. Generation of `cld` instructions can be suppressed with the `-mno-cld` compiler option in this case.

`-mvzeroupper`
: This option instructs GCC to emit a `vzeroupper` instruction before a transfer of control flow out of the function to minimize the AVX to SSE transition penalty as well as remove unnecessary `zeroupper` intrinsics.

`-mprefer-avx128`
: This option instructs GCC to use 128-bit AVX instructions instead of 256-bit AVX instructions in the auto-vectorizer.

`-mprefer-vector-width=`*`opt`*
: This option instructs GCC to use *opt*-bit vector width in instructions instead of default on the selected platform.

`-mpartial-vector-fp-math`
: This option enables GCC to generate floating-point operations that might affect the set of floating-point status flags on partial vectors, where vector elements reside in the low part of the 128-bit SSE register. Unless `-fno-trapping-math` is specified, the compiler guarantees correct behavior by sanitizing all input operands to have zeroes in the unused upper part of the vector register. Note that by using built-in functions or inline assembly with partial vector arguments, NaNs, denormal or invalid values can leak into the upper part of the vector, causing possible performance issues when `-fno-trapping-math` is in effect. These issues can be mitigated by manually sanitizing the upper part of the partial vector argument register or by using `-mdaz-ftz` to set denormals-are-zero (DAZ) flag in the MXCSR register.

  This option is enabled by default.

`-mmove-max=`*`bits`*
: This option instructs GCC to set the maximum number of bits can be moved from memory to memory efficiently to *bits*. The valid *bits* are 128, 256 and 512.

`-mstore-max=`*`bits`*
: This option instructs GCC to set the maximum number of bits can be stored to memory efficiently to *bits*. The valid *bits* are 128, 256 and 512.

'none' No extra limitations applied to GCC other than defined by the selected platform.

'128' Prefer 128-bit vector width for instructions.

'256' Prefer 256-bit vector width for instructions.

'512' Prefer 512-bit vector width for instructions.

-mnoreturn-no-callee-saved-registers
: This option optimizes functions with noreturn attribute or _Noreturn specifier by not saving in the function prologue callee-saved registers which are used in the function (except for the BP register). This option can interfere with debugging of the caller of the noreturn function or any function further up in the call stack, so it is not enabled by default.

-mcx16 This option enables GCC to generate CMPXCHG16B instructions in 64-bit code to implement compare-and-exchange operations on 16-byte aligned 128-bit objects. This is useful for atomic updates of data structures exceeding one machine word in size. The compiler uses this instruction to implement Section 7.9.2 [__sync Builtins], page 859. However, for Section 7.9.1 [__atomic Builtins], page 854, operating on 128-bit integers, a library call is always used.

-msahf This option enables generation of SAHF instructions in 64-bit code. Early Intel Pentium 4 CPUs with Intel 64 support, prior to the introduction of Pentium 4 G1 step in December 2005, lacked the LAHF and SAHF instructions which are supported by AMD64. These are load and store instructions, respectively, for certain status flags. In 64-bit mode, the SAHF instruction is used to optimize fmod, drem, and remainder built-in functions; see Section 7.12 [Other Builtins], page 864, for details.

-mmovbe This option enables use of the movbe instruction to optimize byte swapping of four and eight byte entities.

-mshstk The -mshstk option enables shadow stack built-in functions from x86 Control-flow Enforcement Technology (CET).

-mcrc32 This option enables built-in functions __builtin_ia32_crc32qi, __builtin_ia32_crc32hi, __builtin_ia32_crc32si and __builtin_ia32_crc32di to generate the crc32 machine instruction.

-mmwait This option enables built-in functions __builtin_ia32_monitor, and __builtin_ia32_mwait to generate the monitor and mwait machine instructions.

-mrecip This option enables use of RCPSS and RSQRTSS instructions (and their vectorized variants RCPPS and RSQRTPS) with an additional Newton-Raphson step to increase precision instead of DIVSS and SQRTSS (and their vectorized variants) for single-precision floating-point arguments. These instructions are generated only when -funsafe-math-optimizations is enabled together with -ffinite-math-only and -fno-trapping-math. Note that while the throughput of the sequence is higher than the throughput of the non-reciprocal instruction, the precision of the sequence can be decreased by up to 2 ulp (i.e. the inverse of 1.0 equals 0.99999994).

Note that GCC implements `1.0f/sqrtf(x)` in terms of `RSQRTSS` (or `RSQRTPS`) already with `-ffast-math` (or the above option combination), and doesn't need `-mrecip`.

Also note that GCC emits the above sequence with additional Newton-Raphson step for vectorized single-float division and vectorized `sqrtf(x)` already with `-ffast-math` (or the above option combination), and doesn't need `-mrecip`.

`-mrecip=opt`

This option controls which reciprocal estimate instructions may be used. *opt* is a comma-separated list of options, which may be preceded by a '`!`' to invert the option:

'`all`' Enable all estimate instructions.

'`default`' Enable the default instructions, equivalent to `-mrecip`.

'`none`' Disable all estimate instructions, equivalent to `-mno-recip`.

'`div`' Enable the approximation for scalar division.

'`vec-div`' Enable the approximation for vectorized division.

'`sqrt`' Enable the approximation for scalar square root.

'`vec-sqrt`'
Enable the approximation for vectorized square root.

So, for example, `-mrecip=all,!sqrt` enables all of the reciprocal approximations, except for square root.

`-mveclibabi=type`

Specifies the ABI type to use for vectorizing intrinsics using an external library. Supported values for *type* are '`svml`' for the Intel short vector math library, '`aocl`' for the math library (LibM) from AMD Optimizing CPU Libraries (AOCL) and '`acml`' for the end-of-life AMD core math library (to which AOCL-LibM is the successor). To use this option, both `-ftree-vectorize` and `-funsafe-math-optimizations` have to be enabled, and an SVML or ACML ABI-compatible library must be specified at link time.

GCC currently emits calls to `vmldExp2`, `vmldLn2`, `vmldLog102`, `vmldPow2`, `vmldTanh2`, `vmldTan2`, `vmldAtan2`, `vmldAtanh2`, `vmldCbrt2`, `vmldSinh2`, `vmldSin2`, `vmldAsinh2`, `vmldAsin2`, `vmldCosh2`, `vmldCos2`, `vmldAcosh2`, `vmldAcos2`, `vmlsExp4`, `vmlsLn4`, `vmlsLog104`, `vmlsPow4`, `vmlsTanh4`, `vmlsTan4`, `vmlsAtan4`, `vmlsAtanh4`, `vmlsCbrt4`, `vmlsSinh4`, `vmlsSin4`, `vmlsAsinh4`, `vmlsAsin4`, `vmlsCosh4`, `vmlsCos4`, `vmlsAcosh4` and `vmlsAcos4` for corresponding function type when `-mveclibabi=svml` is used, `amd_vrs4_acosf`, `amd_vrs16_acosf`, `amd_vrd8_asin`, `amd_vrs4_asinf`, `amd_vrs8_asinf`, `amd_vrs16_asinf`, `amd_vrd2_atan`, `amd_vrd8_atan`, `amd_vrs4_atanf`, `amd_vrs8_atanf`, `amd_vrs16_atanf`, `amd_vrd2_cos`, `amd_vrd4_cos`, `amd_vrd8_cos`, `amd_vrs4_cosf`, `amd_vrs8_cosf`, `amd_vrs16_cosf`, `amd_vrs4_coshf`, `amd_vrs8_coshf`, `amd_vrd2_erf`, `amd_vrd4_erf`, `amd_vrd8_erf`, `amd_vrs4_erff`, `amd_vrs8_erff`, `amd_vrs16_erff`, `amd_vrd2_exp`, `amd_vrd4_exp`, `amd_vrd8_exp`, `amd_vrs4_expf`, `amd_vrs8_expf`, amd_vrs16_expf, amd_vrd2_exp10, amd_vrs4_exp10f, amd_vrd2_exp2, amd_vrd4_exp2, amd_vrd8_exp2, amd_vrs4_exp2f, amd_vrs8_exp2f, amd_vrs16_exp2f, amd_vrs4_expm1f, amd_vrd2_log, amd_vrd4_log, amd_vrd8_log, amd_vrs4_logf, amd_vrs8_logf, amd_vrs16_logf, amd_vrd2_log10, amd_vrs4_log10f, amd_vrs8_log10f, amd_vrs16_log10f, amd_vrd2_log1p, amd_vrs4_log1pf, amd_vrd2_log2, amd_vrd4_log2, amd_vrd8_log2, amd_vrs4_log2f, amd_vrs8_log2f, amd_vrs16_log2f, amd_vrd2_pow, amd_vrd4_pow, amd_vrd8_pow, amd_vrs4_powf, amd_vrs8_powf, amd_vrs16_powf, amd_vrd2_sin, amd_vrd4_sin, amd_vrd8_sin, amd_vrs4_sinf, amd_vrs8_sinf, amd_vrs16_sinf, amd_vrd2_tan, amd_vrd4_tan, amd_vrd8_tan, amd_vrs16_tanf, amd_vrs4_tanhf, amd_vrs8_tanhf, amd_vrs16_tanhf for the corresponding function type when `-mveclibabi=aocl` is used, and __vrd2_sin, __vrd2_cos, __vrd2_exp, __vrd2_log, __vrd2_log2, __vrd2_log10, __vrs4_sinf, __vrs4_cosf, __vrs4_expf, __vrs4_logf, __vrs4_log2f, __vrs4_log10f and __vrs4_powf for the corresponding function type when `-mveclibabi=acml` is used.

`-mabi=`*name*
: Generate code for the specified calling convention. Permissible values are 'sysv' for the ABI used on GNU/Linux and other systems, and 'ms' for the Microsoft ABI. The default is to use the Microsoft ABI when targeting Microsoft Windows and the SysV ABI on all other systems. You can control this behavior for specific functions by using the function attributes `ms_abi` and `sysv_abi`. See Section 6.4.1 [Function Attributes], page 621.

`-mforce-indirect-call`
: Force all calls to functions to be indirect. This is useful when using Intel Processor Trace where it generates more precise timing information for function calls.

`-mmanual-endbr`
: Insert ENDBR instruction at function entry only via the `cf_check` function attribute. This is useful when used with the option `-fcf-protection=branch` to control ENDBR insertion at the function entry.

`-mcet-switch`
: By default, CET instrumentation is turned off on switch statements that use a jump table and indirect branch track is disabled. Since jump tables are stored in read-only memory, this does not result in a direct loss of hardening. But if the jump table index is attacker-controlled, the indirect jump may not be constrained by CET. This option turns on CET instrumentation to enable indirect branch track for switch statements with jump tables which leads to the jump targets reachable via any indirect jumps.

`-mcall-ms2sysv-xlogues`
: Due to differences in 64-bit ABIs, any Microsoft ABI function that calls a System V ABI function must consider RSI, RDI and XMM6-15 as clobbered. By default, the code for saving and restoring these registers is emitted inline, resulting in fairly lengthy prologues and epilogues. Using `-mcall-ms2sysv-xlogues` emits prologues and epilogues that use stubs in the static portion of

libgcc to perform these saves and restores, thus reducing function size at the cost of a few extra instructions.

`-mtls-dialect=type`
: Generate code to access thread-local storage using the 'gnu' or 'gnu2' conventions. 'gnu' is the conservative default; 'gnu2' is more efficient, but it may add compile- and run-time requirements that cannot be satisfied on all systems.

`-mpush-args`
`-mno-push-args`
: Use PUSH operations to store outgoing parameters. This method is shorter and usually equally fast as method using SUB/MOV operations and is enabled by default. In some cases disabling it may improve performance because of improved scheduling and reduced dependencies.

`-maccumulate-outgoing-args`
: If enabled, the maximum amount of space required for outgoing arguments is computed in the function prologue. This is faster on most modern CPUs because of reduced dependencies, improved scheduling and reduced stack usage when the preferred stack boundary is not equal to 2. The drawback is a notable increase in code size. This switch implies `-mno-push-args`.

`-mthreads`
: Support thread-safe exception handling on MinGW. Programs that rely on thread-safe exception handling must compile and link all code with the `-mthreads` option. When compiling, `-mthreads` defines `-D_MT`; when linking, it links in a special thread helper library `-lmingwthrd` which cleans up per-thread exception-handling data.

`-mms-bitfields`
`-mno-ms-bitfields`
: Enable/disable bit-field layout compatible with the native Microsoft Windows compiler.

  If `packed` is used on a structure, or if bit-fields are used, it may be that the Microsoft ABI lays out the structure differently than the way GCC normally does. Particularly when moving packed data between functions compiled with GCC and the native Microsoft compiler (either via function call or as data in a file), it may be necessary to access either format.

  This option is enabled by default for Microsoft Windows targets. This behavior can also be controlled locally by use of variable or type attributes. For more information, see Section 6.4.2.15 [x86 Variable Attributes], page 714, and Section 6.4.3.6 [x86 Type Attributes], page 730.

  The Microsoft structure layout algorithm is fairly simple with the exception of the bit-field packing. The padding and alignment of members of structures and whether a bit-field can straddle a storage-unit boundary are determine by these rules:

  1. Structure members are stored sequentially in the order in which they are declared: the first member has the lowest memory address and the last member the highest.

2. Every data object has an alignment requirement. The alignment requirement for all data except structures, unions, and arrays is either the size of the object or the current packing size (specified with either the `aligned` attribute or the `pack` pragma), whichever is less. For structures, unions, and arrays, the alignment requirement is the largest alignment requirement of its members. Every object is allocated an offset so that:

   ```
   offset % alignment_requirement == 0
   ```

3. Adjacent bit-fields are packed into the same 1-, 2-, or 4-byte allocation unit if the integral types are the same size and if the next bit-field fits into the current allocation unit without crossing the boundary imposed by the common alignment requirements of the bit-fields.

MSVC interprets zero-length bit-fields in the following ways:

1. If a zero-length bit-field is inserted between two bit-fields that are normally coalesced, the bit-fields are not coalesced.

   For example:

   ```
   struct
    {
      unsigned long bf_1 : 12;
      unsigned long : 0;
      unsigned long bf_2 : 12;
    } t1;
   ```

   The size of `t1` is 8 bytes with the zero-length bit-field. If the zero-length bit-field were removed, `t1`'s size would be 4 bytes.

2. If a zero-length bit-field is inserted after a bit-field, `foo`, and the alignment of the zero-length bit-field is greater than the member that follows it, `bar`, `bar` is aligned as the type of the zero-length bit-field.

   For example:

   ```
   struct
    {
      char foo : 4;
      short : 0;
      char bar;
    } t2;

   struct
    {
      char foo : 4;
      short : 0;
      double bar;
    } t3;
   ```

   For `t2`, `bar` is placed at offset 2, rather than offset 1. Accordingly, the size of `t2` is 4. For `t3`, the zero-length bit-field does not affect the alignment of `bar` or, as a result, the size of the structure.

   Taking this into account, it is important to note the following:

   1. If a zero-length bit-field follows a normal bit-field, the type of the zero-length bit-field may affect the alignment of the structure as whole. For example, `t2` has a size of 4 bytes, since the zero-length bit-field follows a normal bit-field, and is of type short.

2. Even if a zero-length bit-field is not followed by a normal bit-field, it may still affect the alignment of the structure:

   ```
   struct
    {
      char foo : 6;
      long : 0;
    } t4;
   ```

   Here, `t4` takes up 4 bytes.

3. Zero-length bit-fields following non-bit-field members are ignored:

   ```
   struct
    {
      char foo;
      long : 0;
      char bar;
    } t5;
   ```

   Here, `t5` takes up 2 bytes.

`-mno-align-stringops`
: Do not align the destination of inlined string operations. This switch reduces code size and improves performance in case the destination is already aligned, but GCC doesn't know about it.

`-minline-all-stringops`
: By default GCC inlines string operations only when the destination is known to be aligned to least a 4-byte boundary. This enables more inlining and increases code size, but may improve performance of code that depends on fast `memcpy` and `memset` for short lengths. The option enables inline expansion of `strlen` for all pointer alignments.

`-minline-stringops-dynamically`
: For string operations of unknown size, use run-time checks with inline code for small blocks and a library call for large blocks.

`-mstringop-strategy=`*`alg`*
: Override the internal decision heuristic for the particular algorithm to use for inlining string operations. The allowed values for *alg* are:

  ‘`rep_byte`’
  ‘`rep_4byte`’
  ‘`rep_8byte`’
  : Expand using i386 `rep` prefix of the specified size.

  ‘`byte_loop`’
  ‘`loop`’
  ‘`unrolled_loop`’
  : Expand into an inline loop.

  ‘`libcall`’ Always use a library call.

`-mmemcpy-strategy=`*`strategy`*
: Override the internal decision heuristic to decide if `__builtin_memcpy` should be inlined and what inline algorithm to use when the expected size of the copy operation is known. *strategy* is a comma-separated list of

alg:*max_size*:*dest_align* triplets. *alg* is specified in `-mstringop-strategy`, *max_size* specifies the max byte size with which inline algorithm *alg* is allowed. For the last triplet, the *max_size* must be `-1`. The *max_size* of the triplets in the list must be specified in increasing order. The minimal byte size for *alg* is `0` for the first triplet and `max_size + 1` of the preceding range.

`-mmemset-strategy=strategy`
: The option is similar to `-mmemcpy-strategy=` except that it is to control `__builtin_memset` expansion.

`-momit-leaf-frame-pointer`
: Don't keep the frame pointer in a register for leaf functions. This avoids the instructions to save, set up, and restore frame pointers and makes an extra register available in leaf functions. The option `-momit-leaf-frame-pointer` removes the frame pointer for leaf functions, which might make debugging harder.

`-mtls-direct-seg-refs`
`-mno-tls-direct-seg-refs`
: Controls whether TLS variables may be accessed with offsets from the TLS segment register (`%gs` for 32-bit, `%fs` for 64-bit), or whether the thread base pointer must be added. Whether or not this is valid depends on the operating system, and whether it maps the segment to cover the entire TLS area.

  For systems that use the GNU C Library, the default is on.

`-msse2avx`
`-mno-sse2avx`
: Specify that the assembler should encode SSE instructions with VEX prefix. The option `-mavx` turns this on by default.

`-mfentry`
`-mno-fentry`
: If profiling is active (`-pg`), put the profiling counter call before the prologue. Note: On x86 architectures the attribute `ms_hook_prologue` isn't possible at the moment for `-mfentry` and `-pg`.

`-mrecord-mcount`
`-mno-record-mcount`
: If profiling is active (`-pg`), generate a __mcount_loc section that contains pointers to each profiling call. This is useful for automatically patching and out calls.

`-mnop-mcount`
`-mno-nop-mcount`
: If profiling is active (`-pg`), generate the calls to the profiling functions as NOPs. This is useful when they should be patched in later dynamically. This is likely only useful together with `-mrecord-mcount`.

`-minstrument-return=type`
: Instrument function exit in -pg -mfentry instrumented functions with call to specified function. This only instruments true returns ending with ret, but not sibling calls ending with jump. Valid types are *none* to not instrument, *call* to generate a call to __return__, or *nop5* to generate a 5 byte nop.

`-mrecord-return`
`-mno-record-return`

Generate a __return_loc section pointing to all return instrumentation code.

`-mfentry-name=name`

Set name of __fentry__ symbol called at function entry for -pg -mfentry functions.

`-mfentry-section=name`

Set name of section to record -mrecord-mcount calls (default __mcount_loc).

`-mskip-rax-setup`
`-mno-skip-rax-setup`

When generating code for the x86-64 architecture with SSE extensions disabled, `-mskip-rax-setup` can be used to skip setting up RAX register when there are no variable arguments passed in vector registers.

Warning: Since RAX register is used to avoid unnecessarily saving vector registers on stack when passing variable arguments, the impacts of this option are callees may waste some stack space, misbehave or jump to a random location. GCC 4.4 or newer don't have those issues, regardless the RAX register value.

`-m8bit-idiv`
`-mno-8bit-idiv`

On some processors, like Intel Atom, 8-bit unsigned integer divide is much faster than 32-bit/64-bit integer divide. This option generates a run-time check. If both dividend and divisor are within range of 0 to 255, 8-bit unsigned integer divide is used instead of 32-bit/64-bit integer divide.

`-mavx256-split-unaligned-load`
`-mavx256-split-unaligned-store`

Split 32-byte AVX unaligned load and store.

`-mstack-protector-guard=guard`
`-mstack-protector-guard-reg=reg`
`-mstack-protector-guard-offset=offset`
`-mstack-protector-guard-symbol=symbol`

Generate stack protection code using canary at *guard*. Supported locations are '`global`' for global canary or '`tls`' for per-thread canary in the TLS block (the default). This option has effect only when `-fstack-protector` or `-fstack-protector-all` is specified.

With the latter choice the options `-mstack-protector-guard-reg=reg` and `-mstack-protector-guard-offset=offset` furthermore specify which segment register (`%fs` or `%gs`) to use as base register for reading the canary, and from what offset from that base register. The default for those is as specified in the relevant ABI.

`-mstack-protector-guard-symbol=symbol` overrides the offset with a symbol reference to a canary in the TLS block.

`-mgeneral-regs-only`

Generate code that uses only the general-purpose registers. This prevents the compiler from using floating-point, vector, mask and bound registers.

`-mrelax-cmpxchg-loop`

When emitting a compare-and-swap loop for Section 7.9.2 [__sync Builtins], page 859, and Section 7.9.1 [__atomic Builtins], page 854, lacking a native instruction, optimize for the highly contended case by issuing an atomic load before the `CMPXCHG` instruction, and using the `PAUSE` instruction to save CPU power when restarting the loop.

`-mindirect-branch=`*`choice`*

Convert indirect call and jump with *choice*. The default is '`keep`', which keeps indirect call and jump unmodified. '`thunk`' converts indirect call and jump to call and return thunk. '`thunk-inline`' converts indirect call and jump to inlined call and return thunk. '`thunk-extern`' converts indirect call and jump to external call and return thunk provided in a separate object file. You can control this behavior for a specific function by using the function attribute `indirect_branch`. See Section 6.4.1 [Function Attributes], page 621.

Note that `-mcmodel=large` is incompatible with `-mindirect-branch=thunk` and `-mindirect-branch=thunk-extern` since the thunk function may not be reachable in the large code model.

Note that `-mindirect-branch=thunk-extern` is compatible with `-fcf-protection=branch` since the external thunk can be made to enable control-flow check.

`-mfunction-return=`*`choice`*

Convert function return with *choice*. The default is '`keep`', which keeps function return unmodified. '`thunk`' converts function return to call and return thunk. '`thunk-inline`' converts function return to inlined call and return thunk. '`thunk-extern`' converts function return to external call and return thunk provided in a separate object file. You can control this behavior for a specific function by using the function attribute `function_return`. See Section 6.4.1 [Function Attributes], page 621.

Note that `-mindirect-return=thunk-extern` is compatible with `-fcf-protection=branch` since the external thunk can be made to enable control-flow check.

Note that `-mcmodel=large` is incompatible with `-mfunction-return=thunk` and `-mfunction-return=thunk-extern` since the thunk function may not be reachable in the large code model.

`-mindirect-branch-register`

Force indirect call and jump via register.

`-mharden-sls=`*`choice`*

Generate code to mitigate against straight line speculation (SLS) with *choice*. The default is '`none`' which disables all SLS hardening. '`return`' enables SLS hardening for function returns. '`indirect-jmp`' enables SLS hardening for indirect jumps. '`all`' enables all SLS hardening.

`-mindirect-branch-cs-prefix`

Add CS prefix to call and jmp to indirect thunk with branch target in r8-r15 registers so that the call and jmp instruction length is 6 bytes to allow them to be replaced with 'lfence; call *%r8-r15' or 'lfence; jmp *%r8-r15' at run-time.

-mapx-inline-asm-use-gpr32
: For inline asm support with APX, by default the EGPR feature was disabled to prevent potential illegal instruction with EGPR occurs. To invoke egpr usage in inline asm, use new compiler option -mapx-inline-asm-use-gpr32 and user should ensure the instruction supports EGPR.

These '-m' switches are supported in addition to the above on x86-64 processors in 64-bit environments.

-m32
-m64
-mx32
-m16
-miamcu
: Generate code for a 16-bit, 32-bit or 64-bit environment. The -m32 option sets int, long, and pointer types to 32 bits, and generates code that runs in 32-bit mode.

  The -m64 option sets int to 32 bits and long and pointer types to 64 bits, and generates code for the x86-64 architecture. For Darwin only the -m64 option also turns off the -fno-pic and -mdynamic-no-pic options.

  The -mx32 option sets int, long, and pointer types to 32 bits, and generates code for the x86-64 architecture.

  The -m16 option is the same as -m32, except for that it outputs the .code16gcc assembly directive at the beginning of the assembly output so that the binary can run in 16-bit mode.

  The -miamcu option generates code which conforms to Intel MCU psABI. It requires the -m32 option to be turned on.

-mno-red-zone
: Do not use a so-called "red zone" for x86-64 code. The red zone is mandated by the x86-64 ABI; it is a 128-byte area beyond the location of the stack pointer that is not modified by signal or interrupt handlers and therefore can be used for temporary data without adjusting the stack pointer. The flag -mno-red-zone disables this red zone.

-mcmodel=small
: Generate code for the small code model: the program and its symbols must be linked in the lower 2 GB of the address space. Pointers are 64 bits. Programs can be statically or dynamically linked. This is the default code model.

-mcmodel=kernel
: Generate code for the kernel code model. The kernel runs in the negative 2 GB of the address space. This model has to be used for Linux kernel code.

-mcmodel=medium
: Generate code for the medium model: the program is linked in the lower 2 GB of the address space. Small symbols are also placed there. Symbols with sizes larger than -mlarge-data-threshold are put into large data or BSS sections

and can be located above 2GB. Programs can be statically or dynamically linked.

`-mcmodel=large`
: Generate code for the large model. This model makes no assumptions about addresses and sizes of sections.

`-maddress-mode=long`
: Generate code for long address mode. This is only supported for 64-bit and x32 environments. It is the default address mode for 64-bit environments.

`-maddress-mode=short`
: Generate code for short address mode. This is only supported for 32-bit and x32 environments. It is the default address mode for 32-bit and x32 environments.

`-mneeded`
`-mno-needed`
: Emit GNU_PROPERTY_X86_ISA_1_NEEDED GNU property for Linux target to indicate the micro-architecture ISA level required to execute the binary.

`-mno-direct-extern-access`
: Without `-fpic` nor `-fPIC`, always use the GOT pointer to access external symbols. With `-fpic` or `-fPIC`, treat access to protected symbols as local symbols. The default is `-mdirect-extern-access`.

  Warning: shared libraries compiled with `-mno-direct-extern-access` and executable compiled with `-mdirect-extern-access` may not be binary compatible if protected symbols are used in shared libraries and executable.

`-munroll-only-small-loops`
: Controls conservative small loop unrolling. It is default enabled by O2, and unrolls loop with less than 4 insns by 1 time. Explicit -f[no-]unroll-[all-]loops would disable this flag to avoid any unintended unrolling behavior that user does not want.

`-mlam=`*`choice`*
: LAM(linear-address masking) allows special bits in the pointer to be used for metadata. The default is '`none`'. With '`u48`', pointer bits in positions 62:48 can be used for metadata; With '`u57`', pointer bits in positions 62:57 can be used for metadata.

3.20.55 x86 Windows Options

See Section 3.20.11 [Cygwin and MinGW Options], page 409.

3.20.56 Xstormy16 Options

These options are defined for Xstormy16:

`-msim`
: Choose startup files and linker script suitable for the simulator.

3.20.57 Xtensa Options

These options are supported for Xtensa targets:

-mconst16
-mno-const16
: Enable or disable use of CONST16 instructions for loading constant values. The CONST16 instruction is currently not a standard option from Tensilica. When enabled, CONST16 instructions are always used in place of the standard L32R instructions. The use of CONST16 is enabled by default only if the L32R instruction is not available.

-mfused-madd
-mno-fused-madd
: Enable or disable use of fused multiply/add and multiply/subtract instructions in the floating-point option. This has no effect if the floating-point option is not also enabled. Disabling fused multiply/add and multiply/subtract instructions forces the compiler to use separate instructions for the multiply and add/subtract operations. This may be desirable in some cases where strict IEEE 754-compliant results are required: the fused multiply add/subtract instructions do not round the intermediate result, thereby producing results with *more* bits of precision than specified by the IEEE standard. Disabling fused multiply add/subtract instructions also ensures that the program output is not sensitive to the compiler's ability to combine multiply and add/subtract operations.

-mserialize-volatile
-mno-serialize-volatile
: When this option is enabled, GCC inserts MEMW instructions before volatile memory references to guarantee sequential consistency. The default is -mserialize-volatile. Use -mno-serialize-volatile to omit the MEMW instructions.

-mforce-no-pic
: For targets, like GNU/Linux, where all user-mode Xtensa code must be position-independent code (PIC), this option disables PIC for compiling kernel code.

-mtext-section-literals
-mno-text-section-literals
: These options control the treatment of literal pools. The default is -mno-text-section-literals, which places literals in a separate section in the output file. This allows the literal pool to be placed in a data RAM/ROM, and it also allows the linker to combine literal pools from separate object files to remove redundant literals and improve code size. With -mtext-section-literals, the literals are interspersed in the text section in order to keep them as close as possible to their references. This may be necessary for large assembly files. Literals for each function are placed right before that function.

-mauto-litpools
-mno-auto-litpools
: These options control the treatment of literal pools. The default is -mno-auto-litpools, which places literals in a separate section in the output file

unless `-mtext-section-literals` is used. With `-mauto-litpools` the literals are interspersed in the text section by the assembler. Compiler does not produce explicit `.literal` directives and loads literals into registers with `MOVI` instructions instead of `L32R` to let the assembler do relaxation and place literals as necessary. This option allows assembler to create several literal pools per function and assemble very big functions, which may not be possible with `-mtext-section-literals`.

`-mtarget-align`
`-mno-target-align`

When this option is enabled, GCC instructs the assembler to automatically align instructions to reduce branch penalties at the expense of some code density. The assembler attempts to widen density instructions to align branch targets and the instructions following call instructions. If there are not enough preceding safe density instructions to align a target, no widening is performed. The default is `-mtarget-align`. These options do not affect the treatment of auto-aligned instructions like `LOOP`, which the assembler always aligns, either by widening density instructions or by inserting NOP instructions.

`-mlongcalls`
`-mno-longcalls`

When this option is enabled, GCC instructs the assembler to translate direct calls to indirect calls unless it can determine that the target of a direct call is in the range allowed by the call instruction. This translation typically occurs for calls to functions in other source files. Specifically, the assembler translates a direct `CALL` instruction into an `L32R` followed by a `CALLX` instruction. The default is `-mno-longcalls`. This option should be used in programs where the call target can potentially be out of range. This option is implemented in the assembler, not the compiler, so the assembly code generated by GCC still shows direct call instructions—look at the disassembled object code to see the actual instructions. Note that the assembler uses an indirect call for every cross-file call, not just those that really are out of range.

`-mabi=`*`name`*

Generate code for the specified ABI. Permissible values are: '`call0`', '`windowed`'. Default ABI is chosen by the Xtensa core configuration.

`-mabi=call0`

When this option is enabled function parameters are passed in registers `a2` through `a7`, registers `a12` through `a15` are caller-saved, and register `a15` may be used as a frame pointer. When this version of the ABI is enabled the C preprocessor symbol `__XTENSA_CALL0_ABI__` is defined.

`-mabi=windowed`

When this option is enabled function parameters are passed in registers `a10` through `a15`, and called function rotates register window by 8 registers on entry so that its arguments are found in registers `a2` through `a7`. Register `a7` may be used as a frame pointer. Register window is rotated 8 registers back upon return. When this version of the ABI is enabled the C preprocessor symbol `__XTENSA_WINDOWED_ABI__` is defined.

`-mextra-l32r-costs=n`
: Specify an extra cost of instruction RAM/ROM access for `L32R` instructions, in clock cycles. This affects, when optimizing for speed, whether loading a constant from literal pool using `L32R` or synthesizing the constant from a small one with a couple of arithmetic instructions. The default value is 0.

`-mstrict-align`
`-mno-strict-align`
: Avoid or allow generating memory accesses that may not be aligned on a natural object boundary as described in the architecture specification. The default is `-mno-strict-align` for cores that support both unaligned loads and stores in hardware and `-mstrict-align` for all other cores.

3.20.58 zSeries Options

These are listed under See Section 3.20.44 [S/390 and zSeries Options], page 511.

3.21 Specifying Subprocesses and the Switches to Pass to Them

`gcc` is a driver program. It performs its job by invoking a sequence of other programs to do the work of compiling, assembling and linking. GCC interprets its command-line parameters and uses these to deduce which programs it should invoke, and which command-line options it ought to place on their command lines. This behavior is controlled by *spec strings*. In most cases there is one spec string for each program that GCC can invoke, but a few programs have multiple spec strings to control their behavior. The spec strings built into GCC can be overridden by using the `-specs=` command-line switch to specify a spec file.

Spec files are plain-text files that are used to construct spec strings. They consist of a sequence of directives separated by blank lines. The type of directive is determined by the first non-whitespace character on the line, which can be one of the following:

`%command`
: Issues a *command* to the spec file processor. The commands that can appear here are:

  `%include <file>`
  : Search for *file* and insert its text at the current point in the specs file.

  `%include_noerr <file>`
  : Just like '`%include`', but do not generate an error message if the include file cannot be found.

  `%rename old_name new_name`
  : Rename the spec string *old_name* to *new_name*.

`*[spec_name]:`
: This tells the compiler to create, override or delete the named spec string. All lines after this directive up to the next directive or blank line are considered to be the text for the spec string. If this results in an empty string then the spec is deleted. (Or, if the spec did not exist, then nothing happens.) Otherwise, if the spec does not currently exist a new spec is created. If the spec does exist

then its contents are overridden by the text of this directive, unless the first character of that text is the '+' character, in which case the text is appended to the spec.

`[suffix]:`

Creates a new '`[suffix] spec`' pair. All lines after this directive and up to the next directive or blank line are considered to make up the spec string for the indicated suffix. When the compiler encounters an input file with the named suffix, it processes the spec string in order to work out how to compile that file. For example:

```
.ZZ:
z-compile -input %i
```

This says that any input file whose name ends in '`.ZZ`' should be passed to the program '`z-compile`', which should be invoked with the command-line switch `-input` and with the result of performing the '`%i`' substitution. (See below.)

As an alternative to providing a spec string, the text following a suffix directive can be one of the following:

`@language`

This says that the suffix is an alias for a known *language*. This is similar to using the `-x` command-line switch to GCC to specify a language explicitly. For example:

```
.ZZ:
@c++
```

Says that .ZZ files are, in fact, C++ source files.

`#name` This causes an error messages saying:

```
name compiler not installed on this system.
```

GCC already has an extensive list of suffixes built into it. This directive adds an entry to the end of the list of suffixes, but since the list is searched from the end backwards, it is effectively possible to override earlier entries using this technique.

GCC has the following spec strings built into it. Spec files can override these strings or create their own. Note that individual targets can also add their own spec strings to this list.

```
asm          Options to pass to the assembler
asm_final    Options to pass to the assembler post-processor
cpp          Options to pass to the C preprocessor
cc1          Options to pass to the C compiler
cc1plus      Options to pass to the C++ compiler
endfile      Object files to include at the end of the link
link         Options to pass to the linker
lib          Libraries to include on the command line to the linker
libgcc       Decides which GCC support library to pass to the linker
linker       Sets the name of the linker
startfile    Object files to include at the start of the link
```

Here is a small example of a spec file:

```
%rename lib                 old_lib
```

```
*lib:
--start-group -lgcc -lc -leval1 --end-group %(old_lib)
```

This example renames the spec called '`lib`' to '`old_lib`' and then overrides the previous definition of '`lib`' with a new one. The new definition adds in some extra command-line options before including the text of the old definition.

Spec strings are a list of command-line options to be passed to their corresponding program. In addition, the spec strings can contain '`%`'-prefixed sequences to substitute variable text or to conditionally insert text into the command line. Using these constructs it is possible to generate quite complex command lines.

Here is a table of all defined '`%`'-sequences for spec strings. Note that spaces are not generated automatically around the results of expanding these sequences. Therefore you can concatenate them together or combine them with constant text in a single argument.

`%%` Substitute one '`%`' into the program name or argument.

`%"` Substitute an empty argument.

`%i` Substitute the name of the input file being processed.

`%b` Substitute the basename for outputs related with the input file being processed. This is often the substring up to (and not including) the last period and not including the directory but, unless %w is active, it expands to the basename for auxiliary outputs, which may be influenced by an explicit output name, and by various other options that control how auxiliary outputs are named.

`%B` This is the same as '`%b`', but include the file suffix (text after the last period). Without %w, it expands to the basename for dump outputs.

`%d` Marks the argument containing or following the '`%d`' as a temporary file name, so that that file is deleted if GCC exits successfully. Unlike '`%g`', this contributes no text to the argument.

`%gsuffix` Substitute a file name that has suffix *suffix* and is chosen once per compilation, and mark the argument in the same way as '`%d`'. To reduce exposure to denial-of-service attacks, the file name is now chosen in a way that is hard to predict even when previously chosen file names are known. For example, '`%g.s ... %g.o ... %g.s`' might turn into '`ccUVUUAU.s ccXYAXZ12.o ccUVUUAU.s`'. *suffix* matches the regexp '`[.A-Za-z]*`' or the special string '`%O`', which is treated exactly as if '`%O`' had been preprocessed. Previously, '`%g`' was simply substituted with a file name chosen once per compilation, without regard to any appended suffix (which was therefore treated just like ordinary text), making such attacks more likely to succeed.

`%usuffix` Like '`%g`', but generates a new temporary file name each time it appears instead of once per compilation.

`%Usuffix` Substitutes the last file name generated with '`%usuffix`', generating a new one if there is no such last file name. In the absence of any '`%usuffix`', this is just like '`%gsuffix`', except they don't share the same suffix *space*, so '`%g.s ... %U.s ... %g.s ... %U.s`' involves the generation of two distinct file names, one for each '`%g.s`' and another for each '`%U.s`'. Previously, '`%U`' was simply substituted with a file name chosen for the previous '%u', without regard to any appended suffix.

%j*suffix* Substitutes the name of the HOST_BIT_BUCKET, if any, and if it is writable, and if -save-temps is not used; otherwise, substitute the name of a temporary file, just like '%u'. This temporary file is not meant for communication between processes, but rather as a junk disposal mechanism.

%|*suffix*
%m*suffix* Like '%g', except if -pipe is in effect. In that case '%|' substitutes a single dash and '%m' substitutes nothing at all. These are the two most common ways to instruct a program that it should read from standard input or write to standard output. If you need something more elaborate you can use an '%{pipe:X}' construct: see for example gcc/fortran/lang-specs.h.

%.*SUFFIX* Substitutes *.SUFFIX* for the suffixes of a matched switch's args when it is subsequently output with '%*'. *SUFFIX* is terminated by the next space or %.

%w Marks the argument containing or following the '%w' as the designated output file of this compilation. This puts the argument into the sequence of arguments that '%o' substitutes.

%V Indicates that this compilation produces no output file.

%o Substitutes the names of all the output files, with spaces automatically placed around them. You should write spaces around the '%o' as well or the results are undefined. '%o' is for use in the specs for running the linker. Input files whose names have no recognized suffix are not compiled at all, but they are included among the output files, so they are linked.

%O Substitutes the suffix for object files. Note that this is handled specially when it immediately follows '%g, %u, or %U', because of the need for those to form complete file names. The handling is such that '%O' is treated exactly as if it had already been substituted, except that '%g, %u, and %U' do not currently support additional *suffix* characters following '%O' as they do following, for example, '.o'.

%I Substitute any of -iprefix (made from GCC_EXEC_PREFIX), -isysroot (made from TARGET_SYSTEM_ROOT), -isystem (made from COMPILER_PATH and -B options) and -imultilib as necessary.

%s Current argument is the name of a library or startup file of some sort. Search for that file in a standard list of directories and substitute the full name found. The current working directory is included in the list of directories scanned.

%T Current argument is the name of a linker script. Search for that file in the current list of directories to scan for libraries. If the file is located insert a --script option into the command line followed by the full path name found. If the file is not found then generate an error message. Note: the current working directory is not searched.

%e*str* Print *str* as an error message. *str* is terminated by a newline. Use this when inconsistent options are detected.

`%nstr` Print *str* as a notice. *str* is terminated by a newline.

`%(name)` Substitute the contents of spec string *name* at this point.

`%x{option}`
Accumulate an option for '`%X`'.

`%X` Output the accumulated linker options specified by a '`%x`' spec string.

`%Y` Output the accumulated assembler options specified by `-Wa`.

`%Z` Output the accumulated preprocessor options specified by `-Wp`.

`%M` Output `multilib_os_dir`.

`%R` Output the concatenation of `target_system_root` and `target_sysroot_suffix`.

`%a` Process the `asm` spec. This is used to compute the switches to be passed to the assembler.

`%A` Process the `asm_final` spec. This is a spec string for passing switches to an assembler post-processor, if such a program is needed.

`%l` Process the `link` spec. This is the spec for computing the command line passed to the linker. Typically it makes use of the '`%L %G %S %D and %E`' sequences.

`%D` Dump out a `-L` option for each directory that GCC believes might contain startup files. If the target supports multilibs then the current multilib directory is prepended to each of these paths.

`%L` Process the `lib` spec. This is a spec string for deciding which libraries are included on the command line to the linker.

`%G` Process the `libgcc` spec. This is a spec string for deciding which GCC support library is included on the command line to the linker.

`%S` Process the `startfile` spec. This is a spec for deciding which object files are the first ones passed to the linker. Typically this might be a file named `crt0.o`.

`%E` Process the `endfile` spec. This is a spec string that specifies the last object files that are passed to the linker.

`%C` Process the `cpp` spec. This is used to construct the arguments to be passed to the C preprocessor.

`%1` Process the `cc1` spec. This is used to construct the options to be passed to the actual C compiler (`cc1`).

`%2` Process the `cc1plus` spec. This is used to construct the options to be passed to the actual C++ compiler (`cc1plus`).

`%*` Substitute the variable part of a matched option. See below. Note that each comma in the substituted string is replaced by a single space.

`%<S` Remove all occurrences of `-S` from the command line. Note—this command is position dependent. '`%`' commands in the spec string before this one see `-S`, '`%`' commands in the spec string after this one do not.

`%<S*` Similar to '`%<S`', but match all switches beginning with `-S`.

`%>S` Similar to '`%<S`', but keep `-S` in the GCC command line.

`%:function(args)`

Call the named function *function*, passing it *args*. *args* is first processed as a nested spec string, then split into an argument vector in the usual fashion. The function returns a string which is processed as if it had appeared literally as part of the current spec.

The following built-in spec functions are provided:

`getenv` The `getenv` spec function takes two arguments: an environment variable name and a string. If the environment variable is not defined, a fatal error is issued. Otherwise, the return value is the value of the environment variable concatenated with the string. For example, if `TOPDIR` is defined as `/path/to/top`, then:

```
%:getenv(TOPDIR /include)
```

expands to `/path/to/top/include`.

`if-exists`

The `if-exists` spec function takes one argument, an absolute pathname to a file. If the file exists, `if-exists` returns the pathname. Here is a small example of its usage:

```
*startfile:
crt0%O%s %:if-exists(crti%O%s) crtbegin%O%s
```

`if-exists-else`

The `if-exists-else` spec function is similar to the `if-exists` spec function, except that it takes two arguments. The first argument is an absolute pathname to a file. If the file exists, `if-exists-else` returns the pathname. If it does not exist, it returns the second argument. This way, `if-exists-else` can be used to select one file or another, based on the existence of the first. Here is a small example of its usage:

```
*startfile:
crt0%O%s %:if-exists(crti%O%s) \
%:if-exists-else(crtbeginT%O%s crtbegin%O%s)
```

`if-exists-then-else`

The `if-exists-then-else` spec function takes at least two arguments and an optional third one. The first argument is an absolute pathname to a file. If the file exists, the function returns the second argument. If the file does not exist, the function returns the third argument if there is one, or NULL otherwise. This can be used to expand one text, or optionally another, based on the existence of a file. Here is a small example of its usage:

```
-l%:if-exists-then-else(%:getenv(VSB_DIR rtnet.h) rtnet net)
```

`sanitize` The `sanitize` spec function takes no arguments. It returns non-NULL if any address, thread or undefined behavior sanitizers are active.

```
%{%:sanitize(address):-funwind-tables}
```

`replace-outfile`
: The `replace-outfile` spec function takes two arguments. It looks for the first argument in the outfiles array and replaces it with the second argument. Here is a small example of its usage:

```
%{fgnu-runtime:%:replace-outfile(-lobjc -lobjc-gnu)}
```

`remove-outfile`
: The `remove-outfile` spec function takes one argument. It looks for the first argument in the outfiles array and removes it. Here is a small example its usage:

```
%:remove-outfile(-lm)
```

`version-compare`
: The `version-compare` spec function takes four or five arguments of the following form:

```
<comparison-op> <arg1> [<arg2>] <switch> <result>
```

It returns `result` if the comparison evaluates to true, and NULL if it doesn't. The supported `comparison-op` values are:

`>=` True if `switch` is a later (or same) version than `arg1`

`!>` Opposite of `>=`

`<` True if `switch` is an earlier version than `arg1`

`!<` Opposite of `<`

`><` True if `switch` is `arg1` or later, and earlier than `arg2`

`<>` True if `switch` is earlier than `arg1`, or is `arg2` or later

If the `switch` is not present at all, the condition is false unless the first character of the `comparison-op` is `!`.

```
%:version-compare(>= 10.3 mmacosx-version-min= -lmx)
```

The above example would add `-lmx` if `-mmacosx-version-min=10.3.9` was passed.

`include`
: The `include` spec function behaves much like `%include`, with the advantage that it can be nested inside a spec and thus be conditionalized. It takes one argument, the filename, and looks for it in the startfile path. It always returns NULL.

```
%{static-libasan|static:%:include(libsanitizer.spec)%(link_libasan)}
```

`pass-through-libs`
: The `pass-through-libs` spec function takes any number of arguments. It finds any `-l` options and any non-options ending in `.a` (which it assumes are the names of linker input library archive files) and returns a result containing all the found arguments each prepended by `-plugin-opt=-pass-through=` and joined by spaces. This list is intended to be passed to the LTO linker plugin.

```
%:pass-through-libs(%G %L %G)
```

`print-asm-header`
: The `print-asm-header` function takes no arguments and simply prints a banner like:

```
Assembler options
=================

Use "-Wa,OPTION" to pass "OPTION" to the assembler.
```

It is used to separate compiler options from assembler options in the `--target-help` output.

`gt`
: The `gt` spec function takes two or more arguments. It returns `""` (the empty string) if the second-to-last argument is greater than the last argument, and NULL otherwise. The following example inserts the `link_gomp` spec if the last `-ftree-parallelize-loops=` option given on the command line is greater than 1:

```
%{%:gt(%{ftree-parallelize-loops=*:%*} 1):%:include(libgomp.spec)%(link_gomp)}
```

`debug-level-gt`
: The `debug-level-gt` spec function takes one argument and returns `""` (the empty string) if `debug_info_level` is greater than the specified number, and NULL otherwise.

```
%{%:debug-level-gt(0):%{gdwarf*:--gdwarf2}}
```

`%{S}`
: Substitutes the `-S` switch, if that switch is given to GCC. If that switch is not specified, this substitutes nothing. Note that the leading dash is omitted when specifying this option, and it is automatically inserted if the substitution is performed. Thus the spec string '`%{foo}`' matches the command-line option `-foo` and outputs the command-line option `-foo`.

`%W{S}`
: Like %{*S*} but mark last argument supplied within as a file to be deleted on failure.

`%@{S}`
: Like %{*S*} but puts the result into a `FILE` and substitutes `@FILE` if an `@file` argument has been supplied.

`%{S*}`
: Substitutes all the switches specified to GCC whose names start with `-S`, but which also take an argument. This is used for switches like `-o`, `-D`, `-I`, etc. GCC considers `-o foo` as being one switch whose name starts with '`o`'. %{o*} substitutes this text, including the space. Thus two arguments are generated.

`%{S*&T*}`
: Like %{*S**}, but preserve order of `S` and `T` options (the order of `S` and `T` in the spec is not significant). There can be any number of ampersand-separated variables; for each the wild card is optional. Useful for CPP as '`%{D*&U*&A*}`'.

`%{S:X}`
: Substitutes `X`, if the `-S` switch is given to GCC.

`%{!S:X}`
: Substitutes `X`, if the `-S` switch is *not* given to GCC.

`%{S*:X}`
: Substitutes `X` if one or more switches whose names start with `-S` are specified to GCC. Normally `X` is substituted only once, no matter how many such switches appeared. However, if `%*` appears somewhere in `X`, then `X` is substituted once for each matching switch, with the `%*` replaced by the part of that switch matching the `*`.

If `%*` appears as the last part of a spec sequence then a space is added after the end of the last substitution. If there is more text in the sequence, however, then a space is not generated. This allows the `%*` substitution to be used as part of a larger string. For example, a spec string like this:

```
%{mcu=*:--script=%*/memory.ld}
```

when matching an option like `-mcu=newchip` produces:

```
--script=newchip/memory.ld
```

`%{.S:X}` Substitutes *X*, if processing a file with suffix *S*.

`%{!.S:X}` Substitutes *X*, if *not* processing a file with suffix *S*.

`%{,S:X}` Substitutes *X*, if processing a file for language *S*.

`%{!,S:X}` Substitutes *X*, if not processing a file for language *S*.

`%{S|P:X}` Substitutes *X* if either `-S` or `-P` is given to GCC. This may be combined with '`!`', '`.`', '`,`', and `*` sequences as well, although they have a stronger binding than the '`|`'. If `%*` appears in *X*, all of the alternatives must be starred, and only the first matching alternative is substituted.

For example, a spec string like this:

```
%{.c:-foo} %{!.c:-bar} %{.c|d:-baz} %{!.c|d:-boggle}
```

outputs the following command-line options from the following input command-line options:

```
fred.c        -foo -baz
jim.d         -bar -boggle
-d fred.c     -foo -baz -boggle
-d jim.d      -bar -baz -boggle
```

`%{%:function(args):X}`
Call function named *function* with args *args*. If the function returns non-NULL, then *X* is substituted, if it returns NULL, it isn't substituted.

`%{S:X; T:Y; :D}`
If *S* is given to GCC, substitutes *X*; else if *T* is given to GCC, substitutes *Y*; else substitutes *D*. There can be as many clauses as you need. This may be combined with `.`, `,`, `!`, `|`, and `*` as needed.

The switch matching text *S* in a '`%{S}`', '`%{S:X}`' or similar construct can use a backslash to ignore the special meaning of the character following it, thus allowing literal matching of a character that is otherwise specially treated. For example, '`%{std=iso9899\:1999:X}`' substitutes *X* if the `-std=iso9899:1999` option is given.

The conditional text *X* in a '`%{S:X}`' or similar construct may contain other nested '`%`' constructs or spaces, or even newlines. They are processed as usual, as described above. Trailing white space in *X* is ignored. White space may also appear anywhere on the left side of the colon in these constructs, except between `.` or `*` and the corresponding word.

The `-O`, `-f`, `-m`, and `-W` switches are handled specifically in these constructs. If another value of `-O` or the negated form of a `-f`, `-m`, or `-W` switch is found later in the command line, the earlier switch value is ignored, except with {S*} where *S* is just one letter, which passes all matching options.

The character '|' at the beginning of the predicate text is used to indicate that a command should be piped to the following command, but only if `-pipe` is specified.

It is built into GCC which switches take arguments and which do not. (You might think it would be useful to generalize this to allow each compiler's spec to say which switches take arguments. But this cannot be done in a consistent fashion. GCC cannot even decide which input files have been specified without knowing which switches take arguments, and it must know which input files to compile in order to tell which compilers to run).

GCC also knows implicitly that arguments starting in `-l` are to be treated as compiler output files, and passed to the linker in their proper position among the other output files.

3.22 Environment Variables Affecting GCC

This section describes several environment variables that affect how GCC operates. Some of them work by specifying directories or prefixes to use when searching for various kinds of files. Some are used to specify other aspects of the compilation environment.

Note that you can also specify places to search using options such as `-B`, `-I` and `-L` (see Section 3.17 [Directory Options], page 312). These take precedence over places specified using environment variables, which in turn take precedence over those specified by the configuration of GCC. See Section "Controlling the Compilation Driver `gcc`" in *GNU Compiler Collection (GCC) Internals*.

`LANG`
`LC_CTYPE`
`LC_MESSAGES`
`LC_ALL`
: These environment variables control the way that GCC uses localization information which allows GCC to work with different national conventions. GCC inspects the locale categories `LC_CTYPE` and `LC_MESSAGES` if it has been configured to do so. These locale categories can be set to any value supported by your installation. A typical value is '`en_GB.UTF-8`' for English in the United Kingdom encoded in UTF-8.

  The `LC_CTYPE` environment variable specifies character classification. GCC uses it to determine the character boundaries in a string; this is needed for some multibyte encodings that contain quote and escape characters that are otherwise interpreted as a string end or escape.

  The `LC_MESSAGES` environment variable specifies the language to use in diagnostic messages.

  If the `LC_ALL` environment variable is set, it overrides the value of `LC_CTYPE` and `LC_MESSAGES`; otherwise, `LC_CTYPE` and `LC_MESSAGES` default to the value of the `LANG` environment variable. If none of these variables are set, GCC defaults to traditional C English behavior.

`TMPDIR`
: If `TMPDIR` is set, it specifies the directory to use for temporary files. GCC uses temporary files to hold the output of one stage of compilation which is to be used as input to the next stage: for example, the output of the preprocessor, which is the input to the compiler proper.

GCC_DIAGNOSTICS_LOG

If GCC_DIAGNOSTICS_LOG is set, then additional information about the diagnostics subsystem will be emitted. If it is set to an empty value, then the information will be written to stderr; otherwise, GCC will attempt to open that file and write the information there.

The precise content and format of the information is subject to change; it is intended for use by GCC developers, rather than end-users.

GCC_COMPARE_DEBUG

Setting GCC_COMPARE_DEBUG is nearly equivalent to passing -fcompare-debug to the compiler driver. See the documentation of this option for more details.

GCC_EXEC_PREFIX

If GCC_EXEC_PREFIX is set, it specifies a prefix to use in the names of the subprograms executed by the compiler. No slash is added when this prefix is combined with the name of a subprogram, but you can specify a prefix that ends with a slash if you wish.

If GCC_EXEC_PREFIX is not set, GCC attempts to figure out an appropriate prefix to use based on the pathname it is invoked with.

If GCC cannot find the subprogram using the specified prefix, it tries looking in the usual places for the subprogram.

The default value of GCC_EXEC_PREFIX is *prefix*/lib/gcc/ where *prefix* is the prefix to the installed compiler. In many cases *prefix* is the value of prefix when you ran the configure script.

Other prefixes specified with -B take precedence over this prefix.

This prefix is also used for finding files such as crt0.o that are used for linking.

In addition, the prefix is used in an unusual way in finding the directories to search for header files. For each of the standard directories whose name normally begins with '/usr/local/lib/gcc' (more precisely, with the value of GCC_INCLUDE_DIR), GCC tries replacing that beginning with the specified prefix to produce an alternate directory name. Thus, with -Bfoo/, GCC searches foo/bar just before it searches the standard directory /usr/local/lib/bar. If a standard directory begins with the configured *prefix* then the value of *prefix* is replaced by GCC_EXEC_PREFIX when looking for header files.

COMPILER_PATH

The value of COMPILER_PATH is a colon-separated list of directories, much like PATH. GCC tries the directories thus specified when searching for subprograms, if it cannot find the subprograms using GCC_EXEC_PREFIX.

LIBRARY_PATH

The value of LIBRARY_PATH is a colon-separated list of directories, much like PATH. When configured as a native compiler, GCC tries the directories thus specified when searching for special linker files, if it cannot find them using GCC_EXEC_PREFIX. Linking using GCC also uses these directories when searching for ordinary libraries for the -l option (but directories specified with -L come first).

`LANG` This variable is used to pass locale information to the compiler. One way in which this information is used is to determine the character set to be used when character literals, string literals and comments are parsed in C and C++. When the compiler is configured to allow multibyte characters, the following values for `LANG` are recognized:

- ‘`C-JIS`’ Recognize JIS characters.
- ‘`C-SJIS`’ Recognize SJIS characters.
- ‘`C-EUCJP`’ Recognize EUCJP characters.

If `LANG` is not defined, or if it has some other value, then the compiler uses `mblen` and `mbtowc` as defined by the default locale to recognize and translate multibyte characters.

`GCC_EXTRA_DIAGNOSTIC_OUTPUT`
If `GCC_EXTRA_DIAGNOSTIC_OUTPUT` is set to one of the following values, then additional text will be emitted to stderr when fix-it hints are emitted. `-fdiagnostics-parseable-fixits` and `-fno-diagnostics-parseable-fixits` take precedence over this environment variable.

‘`fixits-v1`’
Emit parseable fix-it hints, equivalent to `-fdiagnostics-parseable-fixits`. In particular, columns are expressed as a count of bytes, starting at byte 1 for the initial column.

‘`fixits-v2`’
As `fixits-v1`, but columns are expressed as display columns, as per `-fdiagnostics-column-unit=display`.

`EXPERIMENTAL_SARIF_SOCKET`
If `EXPERIMENTAL_SARIF_SOCKET` is set in the environment, then the compiler will attempt to connect to a UNIX domain stream socket with that name, and send an `OnSarifResult` JSON-RPC 2.0 notification to it for each diagnostic that occurs, where the value of the notification is a SARIF `result` object.

The compiler will fail immediately if `EXPERIMENTAL_SARIF_SOCKET` is set and it cannot connect to it.

This feature is experimental and subject to change or removal without notice.

Some additional environment variables affect the behavior of the preprocessor.

`CPATH`
`C_INCLUDE_PATH`
`CPLUS_INCLUDE_PATH`
`OBJC_INCLUDE_PATH`
Each variable’s value is a list of directories separated by a special character, much like `PATH`, in which to look for header files. The special character, `PATH_SEPARATOR`, is target-dependent and determined at GCC build time. For Microsoft Windows-based targets it is a semicolon, and for almost all other targets it is a colon.

CPATH specifies a list of directories to be searched as if specified with -I, but after any paths given with -I options on the command line. This environment variable is used regardless of which language is being preprocessed.

The remaining environment variables apply only when preprocessing the particular language indicated. Each specifies a list of directories to be searched as if specified with -isystem, but after any paths given with -isystem options on the command line.

In all these variables, an empty element instructs the compiler to search its current working directory. Empty elements can appear at the beginning or end of a path. For instance, if the value of CPATH is :/special/include, that has the same effect as '-I. -I/special/include'.

DEPENDENCIES_OUTPUT

If this variable is set, its value specifies how to output dependencies for Make based on the non-system header files processed by the compiler. System header files are ignored in the dependency output.

The value of DEPENDENCIES_OUTPUT can be just a file name, in which case the Make rules are written to that file, guessing the target name from the source file name. Or the value can have the form '*file target*', in which case the rules are written to file *file* using *target* as the target name.

In other words, this environment variable is equivalent to combining the options -MM and -MF (see Section 3.14 [Preprocessor Options], page 297), with an optional -MT switch too.

SUNPRO_DEPENDENCIES

This variable is the same as DEPENDENCIES_OUTPUT (see above), except that system header files are not ignored, so it implies -M rather than -MM. However, the dependence on the main input file is omitted. See Section 3.14 [Preprocessor Options], page 297.

SOURCE_DATE_EPOCH

If this variable is set, its value specifies a UNIX timestamp to be used in replacement of the current date and time in the __DATE__ and __TIME__ macros, so that the embedded timestamps become reproducible.

The value of SOURCE_DATE_EPOCH must be a UNIX timestamp, defined as the number of seconds (excluding leap seconds) since 01 Jan 1970 00:00:00 represented in ASCII; identical to the output of date +%s on GNU/Linux and other systems that support the %s extension in the date command.

The value should be a known timestamp such as the last modification time of the source or package and it should be set by the build process.

3.23 Using Precompiled Headers

Often large projects have many header files that are included in every source file. The time the compiler takes to process these header files over and over again can account for nearly all of the time required to build the project. To make builds faster, GCC allows you to *precompile* a header file.

To create a precompiled header file, simply compile it as you would any other file, if necessary using the `-x` option to make the driver treat it as a C or C++ header file. You may want to use a tool like `make` to keep the precompiled header up-to-date when the headers it contains change.

A precompiled header file is searched for when `#include` is seen in the compilation. As it searches for the included file (see Section "Search Path" in *The C Preprocessor*) the compiler looks for a precompiled header in each directory just before it looks for the include file in that directory. The name searched for is the name specified in the `#include` with '`.gch`' appended. If the precompiled header file cannot be used, it is ignored.

For instance, if you have `#include "all.h"`, and you have `all.h.gch` in the same directory as `all.h`, then the precompiled header file is used if possible, and the original header is used otherwise.

Alternatively, you might decide to put the precompiled header file in a directory and use `-I` to ensure that directory is searched before (or instead of) the directory containing the original header. Then, if you want to check that the precompiled header file is always used, you can put a file of the same name as the original header in this directory containing an `#error` command.

This also works with `-include`. So yet another way to use precompiled headers, good for projects not designed with precompiled header files in mind, is to simply take most of the header files used by a project, include them from another header file, precompile that header file, and `-include` the precompiled header. If the header files have guards against multiple inclusion, they are skipped because they've already been included (in the precompiled header).

If you need to precompile the same header file for different languages, targets, or compiler options, you can instead make a *directory* named like `all.h.gch`, and put each precompiled header in the directory, perhaps using `-o`. It doesn't matter what you call the files in the directory; every precompiled header in the directory is considered. The first precompiled header encountered in the directory that is valid for this compilation is used; they're searched in no particular order.

There are many other possibilities, limited only by your imagination, good sense, and the constraints of your build system.

A precompiled header file can be used only when these conditions apply:

- Only one precompiled header can be used in a particular compilation.
- A precompiled header cannot be used once the first C token is seen. You can have preprocessor directives before a precompiled header; you cannot include a precompiled header from inside another header.
- The precompiled header file must be produced for the same language as the current compilation. You cannot use a C precompiled header for a C++ compilation.
- The precompiled header file must have been produced by the same compiler binary as the current compilation is using.
- Any macros defined before the precompiled header is included must either be defined in the same way as when the precompiled header was generated, or must not affect the precompiled header, which usually means that they don't appear in the precompiled header at all.

The `-D` option is one way to define a macro before a precompiled header is included; using a `#define` can also do it. There are also some options that define macros implicitly, like `-O` and `-Wdeprecated`; the same rule applies to macros defined this way.

- If debugging information is output when using the precompiled header, using `-g` or similar, the same kind of debugging information must have been output when building the precompiled header. However, a precompiled header built using `-g` can be used in a compilation when no debugging information is being output.
- The same `-m` options must generally be used when building and using the precompiled header. See Section 3.20 [Submodel Options], page 345, for any cases where this rule is relaxed.
- Each of the following options must be the same when building and using the precompiled header:

  ```
  -fexceptions
  ```
- Some other command-line options starting with `-f`, `-p`, or `-O` must be defined in the same way as when the precompiled header was generated. At present, it's not clear which options are safe to change and which are not; the safest choice is to use exactly the same options when generating and using the precompiled header. The following are known to be safe:

  ```
  -fmessage-length=  -fpreprocessed  -fsched-interblock
  -fsched-spec  -fsched-spec-load  -fsched-spec-load-dangerous
  -fsched-verbose=number  -fschedule-insns  -fvisibility=
  -pedantic-errors
  ```
- Address space layout randomization (ASLR) can lead to not binary identical PCH files. If you rely on stable PCH file contents disable ASLR when generating PCH files.

For all of these except the last, the compiler automatically ignores the precompiled header if the conditions aren't met. If you find an option combination that doesn't work and doesn't cause the precompiled header to be ignored, please consider filing a bug report, see Chapter 16 [Bugs], page 1145.

If you do use differing options when generating and using the precompiled header, the actual behavior is a mixture of the behavior for the options. For instance, if you use `-g` to generate the precompiled header but not when using it, you may or may not get debugging information for routines in the precompiled header.

3.24 C++ Modules

Modules are a C++20 language feature. As the name suggests, they provide a modular compilation system, intending to provide both faster builds and better library isolation. The "Merging Modules" paper `https://wg21.link/p1103`, provides the easiest to read set of changes to the standard, although it does not capture later changes.

G++'s modules support is not complete. Other than bugs, the known missing pieces are:

Private Module Fragment
: The Private Module Fragment is recognized, but an error is emitted.

Partition definition visibility rules
: Entities may be defined in implementation partitions, and those definitions are not available outside of the module. This is not implemented, and the definitions are available to extra-module use.

Textual merging of reachable GM entities
Entities may be multiply defined across different header-units. These must be de-duplicated, and this is implemented across imports, or when an import redefines a textually-defined entity. However the reverse is not implemented—textually redefining an entity that has been defined in an imported header-unit. A redefinition error is emitted.

Standard Library Header Units
The Standard Library is not provided as importable header units. If you want to import such units, you must explicitly build them first. If you do not do this with care, you may have multiple declarations, which the module machinery must merge—compiler resource usage can be affected by how you partition header files into header units.

Modular compilation is *not* enabled with just the `-std=c++20` option. You must explicitly enable it with the `-fmodules` option. It is independent of the language version selected, although in pre-C++20 versions, it is of course an extension.

No new source file suffixes are required. A few suffixes preferred for module interface units by other compilers (e.g. '`.ixx`', '`.cppm`') are supported, but files with these suffixes are treated the same as any other C++ source file.

Compiling a module interface unit produces an additional output (to the assembly or object file), called a Compiled Module Interface (CMI). This encodes the exported declarations of the module. Importing a module reads in the CMI. The import graph is a Directed Acyclic Graph (DAG). You must build imports before the importer.

Header files may themselves be compiled to header units, which are a transitional ability aiming at faster compilation. The `-fmodule-header` option is used to enable this, and implies the `-fmodules` option. These CMIs are named by the fully resolved underlying header file, and thus may be a complete pathname containing subdirectories. If the header file is found at an absolute pathname, the CMI location is still relative to a CMI root directory.

As header files often have no suffix, you commonly have to specify a `-x` option to tell the compiler the source is a header file. You may use `-x c++-header`, `-x c++-user-header` or `-x c++-system-header`. When used in conjunction with `-fmodules`, these all imply an appropriate `-fmodule-header` option. The latter two variants use the user or system include path to search for the file specified. This allows you to, for instance, compile standard library header files as header units, without needing to know exactly where they are installed. Specifying the language as one of these variants also inhibits output of the object file, as header files have no associated object file.

Alternately, or for a module interface unit in an installed location, you can use `-fsearch-include-path` to specify that the main source file should be found on the include path rather than the current directory.

Header units can be used in much the same way as precompiled headers (see Section 3.23 [Precompiled Headers], page 582), but with fewer restrictions: an #include that is translated to a header unit import can appear at any point in the source file, and multiple header units can be used together. In particular, the `-include` strategy works: with the bits/stdc++.h header used for libstdc++ precompiled headers you can

```
g++ -fmodules -x c++-system-header -c bits/stdc++.h
```

```
g++ -fmodules -include bits/stdc++.h mycode.C
```

and any standard library #includes in mycode.C will be skipped, because the import brought in the whole library. This can be a simple way to use modules to speed up compilation without any code changes.

The `-fmodule-only` option disables generation of the associated object file for compiling a module interface. Only the CMI is generated. This option is implied when using the `-fmodule-header` option.

The `-flang-info-include-translate` and `-flang-info-include-translate-not` options notes whether include translation occurs or not. With no argument, the first will note all include translation. The second will note all non-translations of include files not known to intentionally be textual. With an argument, queries about include translation of a header files with that particular trailing pathname are noted. You may repeat this form to cover several different header files. This option may be helpful in determining whether include translation is happening—if it is working correctly, it behaves as if it isn't there at all.

The `-flang-info-module-cmi` option can be used to determine where the compiler is reading a CMI from. Without the option, the compiler is silent when such a read is successful. This option has an optional argument, which will restrict the notification to just the set of named modules or header units specified.

The `-Winvalid-imported-macros` option causes all imported macros to be resolved at the end of compilation. Without this, imported macros are only resolved when expanded or (re)defined. This option detects conflicting import definitions for all macros.

For details of the `-fmodule-mapper` family of options, see Section 3.24.1 [C++ Module Mapper], page 586.

3.24.1 Module Mapper

A module mapper provides a server or file that the compiler queries to determine the mapping between module names and CMI files. It is also used to build CMIs on demand. *Mapper functionality is in its infancy and is intended for experimentation with build system interactions.*

You can specify a mapper with the `-fmodule-mapper=val` option or `CXX_MODULE_MAPPER` environment variable. The value may have one of the following forms:

[*hostname*]:*port*[?*ident*]
: An optional hostname and a numeric port number to connect to. If the hostname is omitted, the loopback address is used. If the hostname corresponds to multiple IPV6 addresses, these are tried in turn, until one is successful. If your host lacks IPv6, this form is non-functional. If you must use IPv4 use `-fmodule-mapper='|ncat ipv4host port'`.

=*socket*[?*ident*]
: A local domain socket. If your host lacks local domain sockets, this form is non-functional.

|*program*[?*ident*] [*args...*]
: A program to spawn, and communicate with on its stdin/stdout streams. Your *PATH* environment variable is searched for the program. Arguments are separated by space characters, (it is not possible for one of the arguments delivered

to the program to contain a space). An exception is if *program* begins with @. In that case *program* (sans @) is looked for in the compiler's internal binary directory. Thus the sample mapper-server can be specified with `@g++-mapper-server`.

`<>`[?*ident*]
`<>`*inout*[?*ident*]
`<`*in*`>`*out*[?*ident*]

Named pipes or file descriptors to communicate over. The first form, `<>`, communicates over stdin and stdout. The other forms allow you to specify a file descriptor or name a pipe. A numeric value is interpreted as a file descriptor, otherwise named pipe is opened. The second form specifies a bidirectional pipe and the last form allows specifying two independent pipes. Using file descriptors directly in this manner is fragile in general, as it can require the cooperation of intermediate processes. In particular using stdin & stdout is fraught with danger as other compiler options might also cause the compiler to read stdin or write stdout, and it can have unfortunate interactions with signal delivery from the terminal.

file[?*ident*]

A mapping file consisting of space-separated module-name, filename pairs, one per line. Only the mappings for the direct imports and any module export name need be provided. If other mappings are provided, they override those stored in any imported CMI files. A repository root may be specified in the mapping file by using '`$root`' as the module name in the first active line. Use of this option will disable any default module->CMI name mapping.

As shown, an optional *ident* may suffix the first word of the option, indicated by a '`?`' prefix. The value is used in the initial handshake with the module server, or to specify a prefix on mapping file lines. In the server case, the main source file name is used if no *ident* is specified. In the file case, all non-blank lines are significant, unless a value is specified, in which case only lines beginning with *ident* are significant. The *ident* must be separated by whitespace from the module name. Be aware that '`<`', '`>`', '`?`', and '`|`' characters are often significant to the shell, and therefore may need quoting.

The mapper is connected to or loaded lazily, when the first module mapping is required. The networking protocols are only supported on hosts that provide networking. If no mapper is specified a default is provided.

A project-specific mapper is expected to be provided by the build system that invokes the compiler. It is not expected that a general-purpose server is provided for all compilations. As such, the server will know the build configuration, the compiler it invoked, and the environment (such as working directory) in which that is operating. As it may parallelize builds, several compilations may connect to the same socket.

The default mapper generates CMI files in a '`gcm.cache`' directory. CMI files have a '`.gcm`' suffix. The module unit name is used directly to provide the basename. Header units construct a relative path using the underlying header file name. If the path is already relative, a '`,`' directory is prepended. Internal '`..`' components are translated to '`,,`'. No attempt is made to canonicalize these filenames beyond that done by the preprocessor's include search algorithm, as in general it is ambiguous when symbolic links are present.

The mapper protocol was published as "A Module Mapper" https://wg21.link/p1184. The implementation is provided by libcody, https://github.com/urnathan/libcody, which specifies the canonical protocol definition. A proof of concept server implementation embedded in make was described in "Make Me A Module", https://wg21.link/p1602.

3.24.2 Module Preprocessing

Modules affect preprocessing because of header units and include translation. Some uses of the preprocessor as a separate step either do not produce a correct output, or require CMIs to be available.

Header units import macros. These macros can affect later conditional inclusion, which therefore can cascade to differing import sets. When preprocessing, it is necessary to load the CMI. If a header unit is unavailable, the preprocessor issues a warning and continue (when not just preprocessing, an error is emitted). Detecting such imports requires preprocessor tokenization of the input stream to phase 4 (macro expansion).

Include translation converts `#include`, `#include_next` and `#import` directives to internal `import` declarations. Whether a particular directive is translated is controlled by the module mapper. Header unit names are canonicalized during preprocessing.

Dependency information can be emitted for module import, extending the functionality of the various `-M` options. Detection of import declarations requires phase 4 handling of preprocessor directives, but does not require macro expansion, so it is not necessary to use `-MD`. See also `-fdeps-*` for an alternate format for module dependency information.

The `-save-temps` option uses `-fdirectives-only` for preprocessing, and preserve the macro definitions in the preprocessed output. Usually you also want to use this option when explicitly preprocessing a header-unit, or consuming such preprocessed output:

```
g++ -fmodules -E -fdirectives-only my-header.hh -o my-header.ii
g++ -x c++-header -fmodules -fpreprocessed -fdirectives-only my-header.ii
```

3.24.3 Compiled Module Interface

CMIs are an additional artifact when compiling named module interfaces, partitions or header units. These are read when importing. CMI contents are implementation-specific, and in GCC's case tied to the compiler version. Consider them a rebuildable cache artifact, not a distributable object.

When creating an output CMI, any missing directory components are created in a manner that is safe for concurrent builds creating multiple, different, CMIs within a common subdirectory tree.

CMI contents are written to a temporary file, which is then atomically renamed. Observers either see old contents (if there is an existing file), or complete new contents. They do not observe the CMI during its creation. This is unlike object file writing, which may be observed by an external process.

CMIs are read in lazily, if the host OS provides `mmap` functionality. Generally blocks are read when name lookup or template instantiation occurs. To inhibit this, the `-fno-module-lazy` option may be used.

The `--param lazy-modules=n` parameter controls the limit on the number of concurrently open module files during lazy loading. Should more modules be imported, an LRU algorithm is used to determine which files to close—until that file is needed again. This limit may be exceeded with deep module dependency hierarchies. With large code bases there may be more imports than the process limit of file descriptors. By default, the limit is a few less than the per-process file descriptor hard limit, if that is determinable.[2]

GCC CMIs use ELF32 as an architecture-neutral encapsulation mechanism. You may use `readelf` to inspect them, although section contents are largely undecipherable. There is a section named `.gnu.c++.README`, which contains human-readable text. Other than the first line, each line consists of *tag*`: value` tuples.

```
> readelf -p.gnu.c++.README gcm.cache/foo.gcm

String dump of section '.gnu.c++.README':
  [     0]  GNU C++ primary module interface
  [    21]  compiler: 11.0.0 20201116 (experimental) [c++-modules revision 20201116-0454]
  [    6f]  version: 2020/11/16-04:54
  [    89]  module: foo
  [    95]  source: c_b.ii
  [    a4]  dialect: C++20/coroutines
  [    be]  cwd: /data/users/nathans/modules/obj/x86_64/gcc
  [    ee]  repository: gcm.cache
  [   104]  buildtime: 2020/11/16 15:03:21 UTC
  [   127]  localtime: 2020/11/16 07:03:21 PST
  [   14a]  export: foo:part1 foo-part1.gcm
```

Amongst other things, this lists the source that was built, C++ dialect used and imports of the module.[3] The timestamp is the same value as that provided by the `__DATE__` & `__TIME__` macros, and may be explicitly specified with the environment variable `SOURCE_DATE_EPOCH`. For further details see Section 3.22 [Environment Variables], page 579.

A set of related CMIs may be copied, provided the relative pathnames are preserved.

The `.gnu.c++.README` contents do not affect CMI integrity, and it may be removed or altered. The section numbering of the sections whose names do not begin with `.gnu.c++.`, or are not the string section is significant and must not be altered.

---

[2] Where applicable the soft limit is incremented as needed towards the hard limit.

[3] The precise contents of this output may change.

4 C Implementation-Defined Behavior

A conforming implementation of ISO C is required to document its choice of behavior in each of the areas that are designated "implementation defined". The following lists all such areas, along with the section numbers from the ISO/IEC 9899:1990, ISO/IEC 9899:1999, ISO/IEC 9899:2011 and ISO/IEC 9899:2024 standards. Some areas are only implementation-defined in one version of the standard.

Some choices depend on the externally determined ABI for the platform (including standard character encodings) which GCC follows; these are listed as "determined by ABI" below. See Chapter 10 [Binary Compatibility], page 1091, and `https://gcc.gnu.org/readings.html`. Some choices are documented in the preprocessor manual. See Section "Implementation-defined behavior" in *The C Preprocessor*. Some choices are made by the library and operating system (or other environment when compiling for a freestanding environment); refer to their documentation for details.

4.1 Translation

- *How a diagnostic is identified (C90 3.7, C99 and C11 3.10, C23 3.13, C90, C99 and C11 5.1.1.3, C23 5.2.1.3).*

  Diagnostics consist of all the output sent to stderr by GCC.

- *Whether each nonempty sequence of white-space characters other than new-line is retained or replaced by one space character in translation phase 3 (C90, C99 and C11 5.1.1.2, C23 5.2.1.2).*

  See Section "Implementation-defined behavior" in *The C Preprocessor*.

4.2 Environment

The behavior of most of these points are dependent on the implementation of the C library, and are not defined by GCC itself.

- *The mapping between physical source file multibyte characters and the source character set in translation phase 1 (C90, C99 and C11 5.1.1.2, C23 5.2.1.2).*

  See Section "Implementation-defined behavior" in *The C Preprocessor*.

4.3 Identifiers

- *Which additional multibyte characters may appear in identifiers and their correspondence to universal character names (C99 and C11 6.4.2, C23 6.4.3).*

  See Section "Implementation-defined behavior" in *The C Preprocessor*.

- *The number of significant initial characters in an identifier (C90 6.1.2, C90, C99 and C11 5.2.4.1, C23 5.3.5.2, C99 and C11 6.4.2, C23 6.4.3).*

  For internal names, all characters are significant. For external names, the number of significant characters are defined by the linker; for almost all targets, all characters are significant.

- *Whether case distinctions are significant in an identifier with external linkage (C90 6.1.2).*

This is a property of the linker. C99 and later require that case distinctions are always significant in identifiers with external linkage and systems without this property are not supported by GCC.

4.4 Characters

- *The number of bits in a byte (C90 3.4, C99 and C11 3.6, C23 3.7).*

  Determined by ABI.
- *The values of the members of the execution character set (C90, C99 and C11 5.2.1, C23 5.3.1).*

  Determined by ABI.
- *The unique value of the member of the execution character set produced for each of the standard alphabetic escape sequences (C90, C99 and C11 5.2.2, C23 5.3.3).*

  Determined by ABI.
- *The value of a* `char` *object into which has been stored any character other than a member of the basic execution character set (C90 6.1.2.5, C99, C11 and C23 6.2.5).*

  Determined by ABI.
- *Which of* `signed char` *or* `unsigned char` *has the same range, representation, and behavior as "plain"* `char` *(C90 6.1.2.5, C90 6.2.1.1, C99, C11 and C23 6.2.5, C99 and C11 6.3.1.1, C23 6.3.2.1).*

  Determined by ABI. The options `-funsigned-char` and `-fsigned-char` change the default. See Section 3.4 [Options Controlling C Dialect], page 45.
- *The literal encoding, which maps of the characters of the execution character set to the values in a character constant or string literal (C23 6.2.9, C23 6.4.5.5).*

  Determined by ABI.
- *The wide literal encoding, of the characters of the execution character set to the values in a* `wchar_t` *character constant or* `wchar_t` *string literal (C23 6.2.9, C23 6.4.5.5).*

  Determined by ABI.
- *The mapping of members of the source character set (in character constants and string literals) to members of the execution character set (C90 6.1.3.4, C99 and C11 6.4.4.4, C23 6.4.5.5, C90, C99 and C11 5.1.1.2, C23 5.2.1.2).*

  Determined by ABI.
- *The value of an integer character constant containing more than one character or containing a character or escape sequence that does not map to a single-byte execution character (C90 6.1.3.4, C99 and C11 6.4.4.4, C23 6.4.5.5).*

  See Section "Implementation-defined behavior" in *The C Preprocessor*.
- *The value of a wide character constant containing more than one multibyte character or a single multibyte character that maps to multiple members of the extended execution character set, or containing a multibyte character or escape sequence not represented in the extended execution character set (C90 6.1.3.4, C99 and C11 6.4.4.4, C23 6.4.5.5).*

  See Section "Implementation-defined behavior" in *The C Preprocessor*.
- *The current locale used to convert a wide character constant consisting of a single multibyte character that maps to a member of the extended execution character set into a corresponding wide character code (C90 6.1.3.4, C99 and C11 6.4.4.4, C23 6.4.5.5).*

See Section “Implementation-defined behavior” in *The C Preprocessor*.

- *Whether differently-prefixed wide string literal tokens can be concatenated and, if so, the treatment of the resulting multibyte character sequence (C11 6.4.5).*

  Such tokens may not be concatenated.

- *The current locale used to convert a wide string literal into corresponding wide character codes (C90 6.1.4, C99 and C11 6.4.5, C23 6.4.6).*

  See Section “Implementation-defined behavior” in *The C Preprocessor*.

- *The value of a string literal containing a multibyte character or escape sequence not represented in the execution character set (C90 6.1.4, C99 and C11 6.4.5, C23 6.4.6).*

  See Section “Implementation-defined behavior” in *The C Preprocessor*.

- *The encoding of any of* `wchar_t`*,* `char16_t`*, and* `char32_t` *where the corresponding standard encoding macro (*`__STDC_ISO_10646__`*,* `__STDC_UTF_16__`*, or* `__STDC_UTF_32__`*) is not defined (C11 6.10.8.2, C23 6.10.10.3).*

  See Section “Implementation-defined behavior” in *The C Preprocessor*. `char16_t` and `char32_t` literals are always encoded in UTF-16 and UTF-32 respectively.

4.5 Integers

- *Any extended integer types that exist in the implementation (C99, C11 and C23 6.2.5).*

  GCC does not support any extended integer types.

- *Whether signed integer types are represented using sign and magnitude, two’s complement, or one’s complement, and whether the extraordinary value is a trap representation or an ordinary value (C99 and C11 6.2.6.2).*

  GCC supports only two’s complement integer types, and all bit patterns are ordinary values. C23 requires signed integer types to be two’s complement.

- *The rank of any extended integer type relative to another extended integer type with the same precision (C99 and C11 6.3.1.1, C23 6.3.2.1).*

  GCC does not support any extended integer types.

- *The result of, or the signal raised by, converting an integer to a signed integer type when the value cannot be represented in an object of that type (C90 6.2.1.2, C99 and C11 6.3.1.3, C23 6.3.2.3).*

  For conversion to a type of width N, the value is reduced modulo 2^N to be within range of the type; no signal is raised.

- *The results of some bitwise operations on signed integers (C90 6.3, C99 and C11 6.5, C23 6.5.1).*

  Bitwise operators act on the representation of the value including both the sign and value bits, where the sign bit is considered immediately above the highest-value value bit. Signed ‘`>>`’ acts on negative numbers by sign extension.

  As an extension to the C language, GCC does not use the latitude given in C99 and later to treat certain aspects of signed ‘`<<`’ as undefined. However, `-fsanitize=shift` (and `-fsanitize=undefined`) will diagnose such cases. They are also diagnosed where constant expressions are required.

- *The sign of the remainder on integer division (C90 6.3.5).*

  GCC always follows the C99 and later requirement that the result of division is truncated towards zero.

4.6 Floating Point

- *The accuracy of the floating-point operations and of the library functions in* `<math.h>` *and* `<complex.h>` *that return floating-point results (C90, C99 and C11 5.2.4.2.2, C23 5.3.5.3.3).*

  The accuracy is unknown.
- *The rounding behaviors characterized by non-standard values of* `FLT_ROUNDS` *(C90, C99 and C11 5.2.4.2.2, C23 5.3.5.3.3).*

  GCC does not use such values.
- *The evaluation methods characterized by non-standard negative values of* `FLT_EVAL_METHOD` *(C99 and C11 5.2.4.2.2, C23 5.3.5.3.3).*

  GCC does not use such values.
- *The evaluation methods characterized by non-standard negative values of* `DEC_EVAL_METHOD` *(C23 5.3.5.3.4).*

  GCC does not use such values.
- *If decimal floating types are supported (C23 6.2.5).*

  These are supported for certain AArch64, i386, x86-64, PowerPC and S/390 targets only.
- *The direction of rounding when an integer is converted to a floating-point number that cannot exactly represent the original value (C90 6.2.1.3, C99 and C11 6.3.1.4, C23 6.3.2.4).*

  C99 Annex F is followed.
- *The direction of rounding when a floating-point number is converted to a narrower floating-point number (C90 6.2.1.4, C99 and C11 6.3.1.5, C23 6.3.2.5).*

  C99 Annex F is followed.
- *How the nearest representable value or the larger or smaller representable value immediately adjacent to the nearest representable value is chosen for certain floating constants (C90 6.1.3.1, C99 and C11 6.4.4.2, C23 6.4.5.3).*

  C99 Annex F is followed.
- *Whether and how floating expressions are contracted when not disallowed by the* `FP_CONTRACT` *pragma (C99 and C11 6.5, C23 6.5.1).*

  Expressions are currently only contracted if `-ffp-contract=fast`, `-funsafe-math-optimizations` or `-ffast-math` are used. This is subject to change.
- *The default state for the* `FENV_ACCESS` *pragma (C99 and C11 7.6.1, C23 7.6.2).*

  This pragma is not implemented, but the default is to “off” unless `-frounding-math` is used and `-fno-trapping-math` is not in which case it is “on”.
- *Additional floating-point exceptions, rounding modes, environments, and classifications, and their macro names (C99, C11 and C23 7.6, C99, C11 and C23 7.12).*

This is dependent on the implementation of the C library, and is not defined by GCC itself.

- *The default state for the* `FP_CONTRACT` *pragma (C99 and C11 7.12.2, C23 7.12.3).*

  This pragma is not implemented. Expressions are currently only contracted if `-ffp-contract=fast`, `-funsafe-math-optimizations` or `-ffast-math` are used. This is subject to change.

- *Whether the "inexact" floating-point exception can be raised when the rounded result actually does equal the mathematical result in an IEC 60559 conformant implementation (C99 F.9).*

  This is dependent on the implementation of the C library, and is not defined by GCC itself.

- *Whether the "underflow" (and "inexact") floating-point exception can be raised when a result is tiny but not inexact in an IEC 60559 conformant implementation (C99 F.9).*

  This is dependent on the implementation of the C library, and is not defined by GCC itself.

4.7 Constant expressions

- *Whether or not an expression not explicitly sanctioned by this document is an extended constant expression, whether or not such extended constant expressions can be used in the same contexts as this document, and whether or not such extended constant expressions can affect potentially detectable semantic changes in the program (C23 6.6).*

  The only extended constant expressions are those using other GNU extensions to the C language. Such extended constant expressions include integer constant expressions and arithmetic constant expressions.

4.8 Arrays and Pointers

- *The result of converting a pointer to an integer or vice versa (C90 6.3.4, C99 and C11 6.3.2.3, C23 6.3.3.3).*

  A cast from pointer to integer discards most-significant bits if the pointer representation is larger than the integer type, sign-extends[1] if the pointer representation is smaller than the integer type, otherwise the bits are unchanged.

  A cast from integer to pointer discards most-significant bits if the pointer representation is smaller than the integer type, extends according to the signedness of the integer type if the pointer representation is larger than the integer type, otherwise the bits are unchanged.

  When casting from pointer to integer and back again, the resulting pointer must reference the same object as the original pointer, otherwise the behavior is undefined. That is, one may not use integer arithmetic to avoid the undefined behavior of pointer arithmetic as proscribed in C99 and C11 6.5.6/8.

[1] Future versions of GCC may zero-extend, or use a target-defined `ptr_extend` pattern. Do not rely on sign extension.

- *The size of the result of subtracting two pointers to elements of the same array (C90 6.3.6, C99 and C11 6.5.6, C23 6.5.7).*

  The value is as specified in the standard and the type is determined by the ABI.

4.9 Hints

- *The extent to which suggestions made by using the* `register` *storage-class specifier are effective (C90 6.5.1, C99 and C11 6.7.1, C23 6.7.2).*

  The `register` specifier affects code generation only in these ways:

  - When used as part of the register variable extension, see Section 6.11.6 [Explicit Register Variables], page 807.
  - When `-O0` is in use, the compiler allocates distinct stack memory for all variables that do not have the `register` storage-class specifier; if `register` is specified, the variable may have a shorter lifespan than the code would indicate and may never be placed in memory.
  - On some rare x86 targets, `setjmp` doesn't save the registers in all circumstances. In those cases, GCC doesn't allocate any variables in registers unless they are marked `register`.

- *The extent to which suggestions made by using the inline function specifier are effective (C99 and C11 6.7.4, C23 6.7.5).*

  GCC will not inline any functions if the `-fno-inline` option is used or if `-O0` is used. Otherwise, GCC may still be unable to inline a function for many reasons; the `-Winline` option may be used to determine if a function has not been inlined and why not.

4.10 Structures, Unions, Enumerations, and Bit-Fields

- *A member of a union object is accessed using a member of a different type (C90 6.3.2.3).*

  The relevant bytes of the representation of the object are treated as an object of the type used for the access. See [Type-punning], page 224. This may be a trap representation.

- *Whether a "plain"* `int` *bit-field is treated as a* `signed int` *bit-field or as an* `unsigned int` *bit-field (C90 6.5.2, C90 6.5.2.1, C99 and C11 6.7.2, C23 6.7.3, C99 and C11 6.7.2.1, C23 6.7.3.2).*

  By default it is treated as `signed int` but this may be changed by the `-funsigned-bitfields` option.

- *Allowable bit-field types other than* `_Bool`, `signed int`, *and* `unsigned int` *(C99 and C11 6.7.2.1, C23 6.7.3.2).*

  Other integer types, such as `long int`, and enumerated types are permitted even in strictly conforming mode.

- *Whether atomic types are permitted for bit-fields (C11 6.7.2.1, C23 6.7.3.2).*

  Atomic types are not permitted for bit-fields.

- *Whether a bit-field can straddle a storage-unit boundary (C90 6.5.2.1, C99 and C11 6.7.2.1, C23 6.7.3.2).*

  Determined by ABI.

- *The order of allocation of bit-fields within a unit (C90 6.5.2.1, C99 and C11 6.7.2.1, C23 6.7.3.2).*

  Determined by ABI.

- *The alignment of non-bit-field members of structures (C90 6.5.2.1, C99 and C11 6.7.2.1, C23 6.7.3.2).*

  Determined by ABI.

- *The integer type compatible with each enumerated type (C90 6.5.2.2, C99 and C11 6.7.2.2, C23 6.7.3.3).*

  Normally, the type is `unsigned int` if there are no negative values in the enumeration, otherwise `int`. If `-fshort-enums` is specified, then if there are negative values it is the first of `signed char`, `short` and `int` that can represent all the values, otherwise it is the first of `unsigned char`, `unsigned short` and `unsigned int` that can represent all the values.

  On some targets, `-fshort-enums` is the default; this is determined by the ABI.

4.11 Qualifiers

- *What constitutes an access to an object that has volatile-qualified type (C90 6.5.3, C99 and C11 6.7.3, C23 6.7.4).*

  Such an object is normally accessed by pointers and used for accessing hardware. In most expressions, it is intuitively obvious what is a read and what is a write. For example

  ```
  volatile int *dst = somevalue;
  volatile int *src = someothervalue;
  *dst = *src;
  ```

  will cause a read of the volatile object pointed to by *src* and store the value into the volatile object pointed to by *dst*. There is no guarantee that these reads and writes are atomic, especially for objects larger than `int`.

  However, if the volatile storage is not being modified, and the value of the volatile storage is not used, then the situation is less obvious. For example

  ```
  volatile int *src = somevalue;
  *src;
  ```

  According to the C standard, such an expression is an rvalue whose type is the unqualified version of its original type, i.e. `int`. Whether GCC interprets this as a read of the volatile object being pointed to or only as a request to evaluate the expression for its side effects depends on this type.

  If it is a scalar type, or on most targets an aggregate type whose only member object is of a scalar type, or a union type whose member objects are of scalar types, the expression is interpreted by GCC as a read of the volatile object; in the other cases, the expression is only evaluated for its side effects.

  When an object of an aggregate type, with the same size and alignment as a scalar type `S`, is the subject of a volatile access by an assignment expression or an atomic function, the access to it is performed as if the object's declared type were `volatile S`.

4.12 Types

- *A program forms the composite type of an enumerated type and a non-enumeration integer type (C23 6.2.7).*

  The composite type is the enumerated type.
- *Whether or not it is supported for a declaration for which a type is inferred to contain a pointer, array, or function declarator (C23 6.7.10).*

  This is not supported.
- *Whether or not it is supported for a declaration for which a type is inferred to contain no or more than one declarators (C23 6.7.10).*

  This is not supported.

4.13 Declarators

- *The maximum number of declarators that may modify an arithmetic, structure or union type (C90 6.5.4).*

  GCC is only limited by available memory.

4.14 Statements

- *The maximum number of `case` values in a `switch` statement (C90 6.6.4.2).*

  GCC is only limited by available memory.

4.15 Preprocessing Directives

See Section "Implementation-defined behavior" in *The C Preprocessor*, for details of these aspects of implementation-defined behavior.

- *The locations within `#pragma` directives where header name preprocessing tokens are recognized (C11 and C23 6.4, C11 6.4.7, C23 6.4.8).*
- *How sequences in both forms of header names are mapped to headers or external source file names (C90 6.1.7, C99 and C11 6.4.7, C23 6.4.8).*
- *Whether the value of a character constant in a constant expression that controls conditional inclusion matches the value of the same character constant in the execution character set (C90 6.8.1, C99 and C11 6.10.1, C23 6.10.2).*
- *Whether the value of a single-character character constant in a constant expression that controls conditional inclusion may have a negative value (C90 6.8.1, C99 and C11 6.10.1, C23 6.10.2).*
- *The places that are searched for an included '`<>`' delimited header, and how the places are specified or the header is identified (C90 6.8.2, C99 and C11 6.10.2, C23 6.10.3).*
- *How the named source file is searched for in an included '`""`' delimited header (C90 6.8.2, C99 and C11 6.10.2, C23 6.10.3).*
- *How the named resource file is searched for in an embedded '`""`' delimited resource name (C23 6.10.4).*
- *The method by which preprocessing tokens (possibly resulting from macro expansion) in a `#include` directive are combined into a header name (C90 6.8.2, C99 and C11 6.10.2, C23 6.10.3).*

- *The nesting limit for* `#include` *processing (C90 6.8.2, C99 and C11 6.10.2, C23 6.10.3).*
- *The method by which preprocessing tokens (possibly resulting from macro expansion) in a* `#embed` *directive are combined into a resource name (C23 6.10.4).*
- *The mapping between a resource's data and the values of the integer constant expressions, if any, in the replacement of a* `#embed` *directive (C23 6.10.4).*
- *The width of a resource located by the* `#embed` *directive (C23 6.10.4).*
- *Whether the '*`#`*' operator inserts a '*`\`*' character before the '*`\`*' character that begins a universal character name in a character constant or string literal (C99 and C11 6.10.3.2, C23 6.10.5.3).*
- *The behavior on each recognized non-*`STDC` `#pragma` *directive (C90 6.8.6, C99 and C11 6.10.6, C23 6.10.8).*

  See Section "Pragmas" in *The C Preprocessor*, for details of pragmas accepted by GCC on all targets. See Section 6.5 [Pragmas Accepted by GCC], page 738, for details of target-specific pragmas.
- *The definitions for* `__DATE__` *and* `__TIME__` *when respectively, the date and time of translation are not available (C90 6.8.8, C99 6.10.8, C11 6.10.8.1, C23 6.10.10.2).*

4.16 Library Functions

The behavior of most of these points are dependent on the implementation of the C library, and are not defined by GCC itself.

- *The null pointer constant to which the macro* `NULL` *expands (C90 7.1.6, C99 7.17, C11 7.19, C23 7.21).*

  In `<stddef.h>`, `NULL` expands to `((void *)0)`. GCC does not provide the other headers which define `NULL` and some library implementations may use other definitions in those headers.

4.17 Architecture

- *The values or expressions assigned to the macros specified in the headers* `<float.h>`, `<limits.h>`, *and* `<stdint.h>` *(C90, C99 and C11 5.2.4.2, C23 5.3.5.3, C99 7.18.2, C99 7.18.3, C11 7.20.2, C11 7.20.3, C23 7.22).*

  Determined by ABI.
- *The result of attempting to indirectly access an object with automatic or thread storage duration from a thread other than the one with which it is associated (C11 and C23 6.2.4).*

  Such accesses are supported, subject to the same requirements for synchronization for concurrent accesses as for concurrent accesses to any object.
- *The number, order, and encoding of bytes in any object (when not explicitly specified in this International Standard) (C99, C11 and C23 6.2.6.1).*

  Determined by ABI.
- *Whether any extended alignments are supported and the contexts in which they are supported (C11 and C23 6.2.8).*

Extended alignments up to 2^{28} (bytes) are supported for objects of automatic storage duration. Alignments supported for objects of static and thread storage duration are determined by the ABI.

- *Valid alignment values other than those returned by an _Alignof expression for fundamental types, if any (C11 and C23 6.2.8).*

  Valid alignments are powers of 2 up to and including 2^{28}.

- *The value of the result of the* `sizeof` *and* `_Alignof` *operators (C90 6.3.3.4, C99 and C11 6.5.3.4, C23 6.5.4.5).*

  Determined by ABI.

4.18 Locale-Specific Behavior

The behavior of these points are dependent on the implementation of the C library, and are not defined by GCC itself.

5 C++ Implementation-Defined Behavior

A conforming implementation of ISO C++ is required to document its choice of behavior in each of the areas that are designated "implementation defined". The following lists all such areas, along with the section numbers from the ISO/IEC 14882:1998 and ISO/IEC 14882:2003 standards. Some areas are only implementation-defined in one version of the standard.

Some choices depend on the externally determined ABI for the platform (including standard character encodings) which GCC follows; these are listed as "determined by ABI" below. See Chapter 10 [Binary Compatibility], page 1091, and `https://gcc.gnu.org/readings.html`. Some choices are documented in the preprocessor manual. See Section "Implementation-defined behavior" in *The C Preprocessor*. Some choices are documented in the corresponding document for the C language. See Chapter 4 [C Implementation], page 591. Some choices are made by the library and operating system (or other environment when compiling for a freestanding environment); refer to their documentation for details.

5.1 Conditionally-Supported Behavior

Each implementation shall include documentation that identifies all conditionally-supported constructs that it does not support (C++0x 1.4).

- *Whether an argument of class type with a non-trivial copy constructor or destructor can be passed to ... (C++0x 5.2.2).*

  Such argument passing is supported, using the same pass-by-invisible-reference approach used for normal function arguments of such types.

5.2 Exception Handling

- *In the situation where no matching handler is found, it is implementation-defined whether or not the stack is unwound before std::terminate() is called (C++98 15.5.1).*

  The stack is not unwound before std::terminate is called.

6 Extensions to the C Language Family

GNU C provides several language features not found in ISO standard C. (The -pedantic option directs GCC to print a warning message if any of these features is used.) To test for the availability of these features in conditional compilation, check for a predefined macro __GNUC__, which is always defined under GCC.

These extensions are available in C and Objective-C. Most of them are also available in C++. See Chapter 8 [Extensions to the C++ Language], page 1061, for extensions that apply *only* to C++.

Some features that are in ISO C99 but not C90 or C++ are also, as extensions, accepted by GCC in C90 mode and in C++.

6.1 Additional Numeric Types

GCC supports additional numeric types, including larger integer types, integer and floating-point complex types, additional floating-point sizes and formats, decimal floating types, and fixed-point types.

6.1.1 128-bit Integers

As an extension the integer scalar type `__int128` is supported for targets which have an integer mode wide enough to hold 128 bits. Simply write `__int128` for a signed 128-bit integer, or `unsigned __int128` for an unsigned 128-bit integer. There is no support in GCC for expressing an integer constant of type `__int128` for targets with `long long` integer less than 128 bits wide.

6.1.2 Double-Word Integers

ISO C99 and ISO C++11 support data types for integers that are at least 64 bits wide, and as an extension GCC supports them in C90 and C++98 modes. Simply write `long long int` for a signed integer, or `unsigned long long int` for an unsigned integer. To make an integer constant of type `long long int`, add the suffix 'LL' to the integer. To make an integer constant of type `unsigned long long int`, add the suffix 'ULL' to the integer.

You can use these types in arithmetic like any other integer types. Addition, subtraction, and bitwise boolean operations on these types are open-coded on all types of machines. Multiplication is open-coded if the machine supports a fullword-to-doubleword widening multiply instruction. Division and shifts are open-coded only on machines that provide special support. The operations that are not open-coded use special library routines that come with GCC.

There may be pitfalls when you use `long long` types for function arguments without function prototypes. If a function expects type `int` for its argument, and you pass a value of type `long long int`, confusion results because the caller and the subroutine disagree about the number of bytes for the argument. Likewise, if the function expects `long long int` and you pass `int`. The best way to avoid such problems is to use prototypes.

6.1.3 Complex Numbers

ISO C99 supports complex floating data types, and as an extension GCC supports them in C90 mode and in C++. GCC also supports complex integer data types which are not part of ISO C99. You can declare complex types using the keyword _Complex. As an extension, the older GNU keyword __complex__ is also supported.

For example, '_Complex double x;' declares x as a variable whose real part and imaginary part are both of type double. '_Complex short int y;' declares y to have real and imaginary parts of type short int; this is not likely to be useful, but it shows that the set of complex types is complete.

To write a constant with a complex data type, use the suffix 'i', 'I', 'j' or 'J' (any one; they are equivalent). For example, 2.5fi has type _Complex float and 3i has type _Complex int. Such a constant always has a pure imaginary value, but you can form any complex value you like by adding one to a real constant. This is part of ISO C2Y and for older C revisions a GNU extension. If you have an ISO C99 conforming C library (such as the GNU C Library), and want to construct complex constants of floating type when using standard versions before ISO C2Y, you should include <complex.h> and use the macros I or _Complex_I instead.

For C++ if -fext-numeric-literals option is enabled, it is also a GNU extension, otherwise it is handled like any other C++ user-defined literal. The ISO C++14 library also defines the 'i' suffix, so C++14 code that includes the '<complex>' header cannot use 'i' for the GNU extension. The 'I', 'j' or 'J' suffixes still have the GNU meaning.

GCC handles both implicit and explicit casts between the _Complex types with different scalar base types by casting both the real and imaginary parts to the base type of the result. GCC also handles implicit and explicit casts from a scalar type to a _Complex type, by giving the imaginary part a zero value.

The C front end can handle implicit and explicit casts from a _Complex type to a scalar type, which uses the value of the real part and ignores the imaginary part. In C++ code, this cast is considered ill-formed and G++ diagnoses it as an error.

GCC has a few extensions which can be used to extract the real and the imaginary part of the complex-valued expression. Note these expressions are lvalues if the *exp* is an lvalue. These expressions operands have the type of a complex type which might get promoted to a complex type from a scalar type. E.g. __real__ (int)x is the same as casting to _Complex int before __real__ is done.

Expression	**Description**
__real__ *exp*	Extract the real part of *exp*.
__imag__ *exp*	Extract the imaginary part of *exp*.

For values of floating-point type, you should use the ISO C99 functions, declared in <complex.h> and also provided as built-in functions by GCC.

Expression	**float**	**double**	**long double**
__real__ *exp*	crealf	creal	creall
__imag__ *exp*	cimagf	cimag	cimagl

The operator '~' performs complex conjugation when used on a value with a complex type. This is a GNU extension; for values of floating type, you should use the ISO C99 functions conjf, conj and conjl, declared in <complex.h> and also provided as built-in functions by GCC. Note unlike the __real__ and __imag__ operators, this operator does not do an implicit cast to the complex type because the '~' is already a normal operator.

GCC can allocate complex automatic variables in a noncontiguous fashion; it's even possible for the real part to be in a register while the imaginary part is on the stack (or vice versa). Only the DWARF debug info format can represent this, so use of DWARF is recommended. If you are using the stabs debug info format, GCC describes a noncontiguous complex variable as if it were two separate variables of noncomplex type. If the variable's actual name is `foo`, the two fictitious variables are named `foo$real` and `foo$imag`. You can examine and set these two fictitious variables with your debugger.

type `__builtin_complex` (*real*, *imag*) [Built-in Function]

The built-in function `__builtin_complex` is provided for use in implementing the ISO C11 macros `CMPLXF`, `CMPLX` and `CMPLXL`. *real* and *imag* must have the same type, a real binary floating-point type, and the result has the corresponding complex type with real and imaginary parts *real* and *imag*. Unlike '*real* + I * *imag*', this works even when infinities, NaNs and negative zeros are involved.

6.1.4 Additional Floating Types

ISO/IEC TS 18661-3:2015 defines C support for additional floating types `_Floatn` and `_Floatnx`, and GCC supports these type names; the set of types supported depends on the target architecture. Constants with these types use suffixes `fn` or `Fn` and `fnx` or `Fnx`. These type names can be used together with `_Complex` to declare complex types.

As an extension, GNU C and GNU C++ support additional floating types, which are not supported by all targets.

- `__float128` is available on i386, x86_64, IA-64, LoongArch and hppa HP-UX, as well as on PowerPC GNU/Linux targets that enable the vector scalar (VSX) instruction set. `__float128` supports the 128-bit floating type. On i386, x86_64, PowerPC, LoongArch and IA-64, other than HP-UX, `__float128` is an alias for `_Float128`. On hppa and IA-64 HP-UX, `__float128` is an alias for `long double`.
- `__float80` is available on the i386, x86_64, and IA-64 targets, and supports the 80-bit (`XFmode`) floating type. It is an alias for the type name `_Float64x` on these targets.
- `__ibm128` is available on PowerPC targets, and provides access to the IBM extended double format which is the current format used for `long double`. When `long double` transitions to `__float128` on PowerPC in the future, `__ibm128` will remain for use in conversions between the two types.

Support for these additional types includes the arithmetic operators: add, subtract, multiply, divide; unary arithmetic operators; relational operators; equality operators; and conversions to and from integer and other floating types. Use a suffix '`w`' or '`W`' in a literal constant of type `__float80` or type `__ibm128`. Use a suffix '`q`' or '`Q`' for `__float128`.

In order to use `_Float128`, `__float128`, and `__ibm128` on PowerPC Linux systems, you must use the `-mfloat128` option. It is expected in future versions of GCC that `_Float128` and `__float128` will be enabled automatically.

The `_Float128` type is supported on all systems where `__float128` is supported or where `long double` has the IEEE binary128 format. The `_Float64x` type is supported on all systems where `__float128` is supported. The `_Float32` type is supported on all systems supporting IEEE binary32; the `_Float64` and `_Float32x` types are supported on all systems supporting IEEE binary64. The `_Float16` type is supported on AArch64 systems by default, on ARM systems when the IEEE format for 16-bit floating-point types is selected with `-mfp16-format=ieee` and, for both C and C++, on x86 systems with SSE2 enabled. GCC does not currently support `_Float128x` on any systems.

On the i386, x86_64, IA-64, and HP-UX targets, you can declare complex types using the corresponding internal complex type, `XCmode` for `__float80` type and `TCmode` for `__float128` type:

```
typedef _Complex float __attribute__((mode(TC))) _Complex128;
typedef _Complex float __attribute__((mode(XC))) _Complex80;
```

On the PowerPC Linux VSX targets, you can declare complex types using the corresponding internal complex type, `KCmode` for `__float128` type and `ICmode` for `__ibm128` type:

```
typedef _Complex float __attribute__((mode(KC))) _Complex_float128;
typedef _Complex float __attribute__((mode(IC))) _Complex_ibm128;
```

6.1.5 Half-Precision Floating Point

GCC supports half-precision (16-bit) floating point on several targets.

It is recommended that portable code use the `_Float16` type defined by ISO/IEC TS 18661-3:2015. See Section 6.1.4 [Floating Types], page 605.

Some targets have peculiarities as follows.

On Arm and AArch64 targets, GCC supports half-precision (16-bit) floating point via the `__fp16` type defined in the Arm C-Language Extensions (ACLE).

Language-level support for the `__fp16` data type is independent of whether GCC generates code using hardware floating-point instructions. In cases where hardware support is not specified, GCC implements conversions between `__fp16` and other types as library calls.

Arm targets support two mutually incompatible half-precision floating-point formats:

- A format that implements IEEE 754-2008 16-bit floating point types, enabled with the `-mfp16-format=ieee` command-line option; this format can represent normalized values in the range of 2^{-14} to 65504. There are 11 bits of significand precision, approximately 3 decimal digits.
- An alternative format that sacrifices NaNs and infinity values, but has a larger range of values that can be represented: 2^{-14} to 131008. This is enabled with the `-mfp16-format=alternative` option.

You must choose one of the formats and use it consistently in your program.

GCC only supports the '`alternative`' format on implementations that support it in hardware; there is no support for conversions to and from this format using library functions. Furthermore, you cannot link together code compiled with one format and code compiled for the other. GCC also supports the `-mfp16-format=none` option, which disables all support for half-precision floating-point types. Code compiled with this option can be linked safely with code compiled for either format.

The Arm architecture extension `FEAT_FP16` (enabled, for example, with `-march=armv8.2-a+fp16`, or `-march=armv8.1-m.main+mve.fp`) defines data processing instructions that only support the '`ieee`' format. The compiler rejects attempts to use the '`alternative`' format when this architecture extension is enabled.

Note that the ACLE has deprecated use of the '`alternative`' format and recommends that only the '`ieee`' format be used.

The default is to compile with `-mfp16-format=ieee`.

In C and C++ there are two related data types:

- `__fp16`, as defined by the Arm C-Language Extensions (ACLE). This can be used to hold either format;
- `_Float16`, which is defined by ISO/IEC TS 18661-3:2015. This is only defined when the format selected is 'ieee'.

The GCC port for AArch64 only supports the IEEE 754-2008 format, and does not have the `-mfp16-format` command-line option.

On x86 targets with SSE2 enabled, GCC supports half-precision (16-bit) floating point via the `_Float16` type. For C++, x86 provides a builtin type named `_Float16` which contains same data format as C.

On x86 targets with SSE2 enabled, without `-mavx512fp16`, all operations are emulated by software emulation and the `float` instructions. The default behavior for `FLT_EVAL_METHOD` is to keep the intermediate result of the operation as 32-bit precision. This may lead to inconsistent behavior between software emulation and AVX512-FP16 instructions. Using `-fexcess-precision=16` forces round back after each operation.

Using `-mavx512fp16` generates AVX512-FP16 instructions instead of software emulation. The default behavior of `FLT_EVAL_METHOD` is to round after each operation. The same is true with `-fexcess-precision=standard` and `-mfpmath=sse`. If there is no `-mfpmath=sse`, `-fexcess-precision=standard` alone does the same thing as before, It is useful for code that does not have `_Float16` and runs on the x87 FPU.

6.1.6 Decimal Floating Types

As an extension, GNU C supports decimal floating types as defined in the N1312 draft of ISO/IEC WDTR24732. Support for decimal floating types in GCC will evolve as the draft technical report changes. Calling conventions for any target might also change. Not all targets support decimal floating types.

The decimal floating types are `_Decimal32`, `_Decimal64`, and `_Decimal128`. They use a radix of ten, unlike the floating types `float`, `double`, and `long double` whose radix is not specified by the C standard but is usually two.

Support for decimal floating types includes the arithmetic operators add, subtract, multiply, divide; unary arithmetic operators; relational operators; equality operators; and conversions to and from integer and other floating types. Use a suffix '`df`' or '`DF`' in a literal constant of type `_Decimal32`, '`dd`' or '`DD`' for `_Decimal64`, and '`dl`' or '`DL`' for `_Decimal128`.

GCC support of decimal float as specified by the draft technical report is incomplete:

- When the value of a decimal floating type cannot be represented in the integer type to which it is being converted, the result is undefined rather than the result value specified by the draft technical report.
- GCC does not provide the C library functionality associated with `math.h`, `fenv.h`, `stdio.h`, `stdlib.h`, and `wchar.h`, which must come from a separate C library implementation. Because of this the GNU C compiler does not define macro `__STDC_DEC_FP__` to indicate that the implementation conforms to the technical report.

Types `_Decimal32`, `_Decimal64`, and `_Decimal128` are supported by the DWARF debug information format.

6.1.7 Fixed-Point Types

As an extension, GNU C supports fixed-point types as defined in the N1169 draft of ISO/IEC DTR 18037. Support for fixed-point types in GCC will evolve as the draft technical report changes. Calling conventions for any target might also change. Not all targets support fixed-point types.

The fixed-point types are `short _Fract`, `_Fract`, `long _Fract`, `long long _Fract`, `unsigned short _Fract`, `unsigned _Fract`, `unsigned long _Fract`, `unsigned long long _Fract`, `_Sat short _Fract`, `_Sat _Fract`, `_Sat long _Fract`, `_Sat long long _Fract`, `_Sat unsigned short _Fract`, `_Sat unsigned _Fract`, `_Sat unsigned long _Fract`, `_Sat unsigned long long _Fract`, `short _Accum`, `_Accum`, `long _Accum`, `long long _Accum`, `unsigned short _Accum`, `unsigned _Accum`, `unsigned long _Accum`, `unsigned long long _Accum`, `_Sat short _Accum`, `_Sat _Accum`, `_Sat long _Accum`, `_Sat long long _Accum`, `_Sat unsigned short _Accum`, `_Sat unsigned _Accum`, `_Sat unsigned long _Accum`, `_Sat unsigned long long _Accum`.

Fixed-point data values contain fractional and optional integral parts. The format of fixed-point data varies and depends on the target machine.

Support for fixed-point types includes:

- prefix and postfix increment and decrement operators (`++`, `--`)
- unary arithmetic operators (`+`, `-`, `!`)
- binary arithmetic operators (`+`, `-`, `*`, `/`)
- binary shift operators (`<<`, `>>`)
- relational operators (`<`, `<=`, `>=`, `>`)
- equality operators (`==`, `!=`)
- assignment operators (`+=`, `-=`, `*=`, `/=`, `<<=`, `>>=`)
- conversions to and from integer, floating-point, or fixed-point types

Use a suffix in a fixed-point literal constant:

- '`hr`' or '`HR`' for `short _Fract` and `_Sat short _Fract`
- '`r`' or '`R`' for `_Fract` and `_Sat _Fract`
- '`lr`' or '`LR`' for `long _Fract` and `_Sat long _Fract`
- '`llr`' or '`LLR`' for `long long _Fract` and `_Sat long long _Fract`
- '`uhr`' or '`UHR`' for `unsigned short _Fract` and `_Sat unsigned short _Fract`
- '`ur`' or '`UR`' for `unsigned _Fract` and `_Sat unsigned _Fract`
- '`ulr`' or '`ULR`' for `unsigned long _Fract` and `_Sat unsigned long _Fract`
- '`ullr`' or '`ULLR`' for `unsigned long long _Fract` and `_Sat unsigned long long _Fract`
- '`hk`' or '`HK`' for `short _Accum` and `_Sat short _Accum`
- '`k`' or '`K`' for `_Accum` and `_Sat _Accum`
- '`lk`' or '`LK`' for `long _Accum` and `_Sat long _Accum`
- '`llk`' or '`LLK`' for `long long _Accum` and `_Sat long long _Accum`
- '`uhk`' or '`UHK`' for `unsigned short _Accum` and `_Sat unsigned short _Accum`
- '`uk`' or '`UK`' for `unsigned _Accum` and `_Sat unsigned _Accum`

- 'ulk' or 'ULK' for `unsigned long _Accum` and `_Sat unsigned long _Accum`
- 'ullk' or 'ULLK' for `unsigned long long _Accum` and `_Sat unsigned long long _Accum`

GCC support of fixed-point types as specified by the draft technical report is incomplete:

- Pragmas to control overflow and rounding behaviors are not implemented.

Fixed-point types are supported by the DWARF debug information format.

6.2 Array, Union, and Struct Extensions

GCC supports several extensions relating to array, union, and struct types, including extensions for aggregate initializers for objects of these types.

6.2.1 Arrays of Variable Length

Variable-length automatic arrays are allowed in ISO C99, and as an extension GCC accepts them in C90 mode and in C++. These arrays are declared like any other automatic arrays, but with a length that is not a constant expression. The storage is allocated at the point of declaration and deallocated when the block scope containing the declaration exits. For example:

```
FILE *
concat_fopen (char *s1, char *s2, char *mode)
{
  char str[strlen (s1) + strlen (s2) + 1];
  strcpy (str, s1);
  strcat (str, s2);
  return fopen (str, mode);
}
```

Jumping or breaking out of the scope of the array name deallocates the storage. Jumping into the scope is not allowed; you get an error message for it.

As an extension, GCC accepts variable-length arrays as a member of a structure or a union. For example:

```
void
foo (int n)
{
  struct S { int x[n]; };
}
```

You can use the function `alloca` to get an effect much like variable-length arrays. The function `alloca` is available in many other C implementations (but not in all). On the other hand, variable-length arrays are more elegant.

There are other differences between these two methods. Space allocated with `alloca` exists until the containing *function* returns. The space for a variable-length array is deallocated as soon as the array name's scope ends, unless you also use `alloca` in this scope.

You can also use variable-length arrays as arguments to functions:

```
struct entry
tester (int len, char data[len][len])
{
  /* ... */
}
```

The length of an array is computed once when the storage is allocated and is remembered for the scope of the array in case you access it with `sizeof`.

If you want to pass the array first and the length afterward, you can use a forward declaration in the parameter list—another GNU extension.

```
struct entry
tester (int len; char data[len][len], int len)
{
  /* ... */
}
```

The '`int len`' before the semicolon is a *parameter forward declaration*, and it serves the purpose of making the name `len` known when the declaration of `data` is parsed.

Lists of parameter forward declarations are terminated by semicolons, and parameter forward declarations are separated within such lists by commas, just like in the regular list of parameter declarations.

You can write any number of lists of parameter forward declaration, but using more than one is unnecessary. The last semicolon is followed by the list of parameter declarations. Each parameter forward declaration must match a parameter declaration in parameter name and data type. ISO C99 does not support parameter forward declarations.

6.2.2 Arrays of Length Zero

Declaring zero-length arrays is allowed in GNU C as an extension. A zero-length array can be useful as the last element of a structure that is really a header for a variable-length object:

```
struct line {
  int length;
  char contents[0];
};

struct line *thisline = (struct line *)
  malloc (sizeof (struct line) + this_length);
thisline->length = this_length;
```

In this example, `thisline->contents` is an array of `char` that can hold up to `thisline->length` bytes.

Although the size of a zero-length array is zero, an array member of this kind may increase the size of the enclosing type as a result of tail padding. The offset of a zero-length array member from the beginning of the enclosing structure is the same as the offset of an array with one or more elements of the same type. The alignment of a zero-length array is the same as the alignment of its elements.

Declaring zero-length arrays in other contexts, including as interior members of structure objects or as non-member objects, is discouraged. Accessing elements of zero-length arrays declared in such contexts is undefined and may be diagnosed.

In the absence of the zero-length array extension, in ISO C90 the `contents` array in the example above would typically be declared to have a single element. Unlike a zero-length array which only contributes to the size of the enclosing structure for the purposes of alignment, a one-element array always occupies at least as much space as a single object of the type. Although using one-element arrays this way is discouraged, GCC handles accesses to trailing one-element array members analogously to zero-length arrays.

The preferred mechanism to declare variable-length types like `struct line` above is the ISO C99 *flexible array member*, with slightly different syntax and semantics:

- Flexible array members are written as `contents[]` without the `0`.
- Flexible array members have incomplete type, and so the `sizeof` operator may not be applied. As a quirk of the original implementation of zero-length arrays, `sizeof` evaluates to zero.
- Flexible array members may only appear as the last member of a `struct` that is otherwise non-empty.
- A structure containing a flexible array member, or a union containing such a structure (possibly recursively), may not be a member of a structure or an element of an array. (However, these uses are permitted by GCC as extensions, see details below.)

The GCC extension accepts a structure containing an ISO C99 *flexible array member*, or a union containing such a structure (possibly recursively) to be a member of a structure.

There are two situations:

- A structure containing a C99 flexible array member, or a union containing such a structure, is the last field of another structure, for example:

  ```
  struct flex  { int length; char data[]; };
  union union_flex { int others; struct flex f; };

  struct out_flex_struct { int m; struct flex flex_data; };
  struct out_flex_union { int n; union union_flex flex_data; };
  ```

  In the above, both `out_flex_struct.flex_data.data[]` and `out_flex_union.flex_data.f.data[]` are considered as flexible arrays too.
- A structure containing a C99 flexible array member, or a union containing such a structure, is not the last field of another structure, for example:

  ```
  struct flex  { int length; char data[]; };

  struct mid_flex { int m; struct flex flex_data; int n; };
  ```

  In the above, accessing a member of the array `mid_flex.flex_data.data[]` might have undefined behavior. Compilers do not handle such a case consistently. Any code relying on this case should be modified to ensure that flexible array members only end up at the ends of structures.

  Please use the warning option `-Wflex-array-member-not-at-end` to identify all such cases in the source code and modify them. This extension is now deprecated.

Non-empty initialization of zero-length arrays is treated like any case where there are more initializer elements than the array holds, in that a suitable warning about "excess elements in array" is given, and the excess elements (all of them, in this case) are ignored.

GCC allows static initialization of flexible array members. This is equivalent to defining a new structure containing the original structure followed by an array of sufficient size to contain the data. E.g. in the following, `f1` is constructed as if it were declared like `f2`.

```
struct f1 {
  int x; int y[];
} f1 = { 1, { 2, 3, 4 } };

struct f2 {
  struct f1 f1; int data[3];
```

```
} f2 = { { 1 }, { 2, 3, 4 } };
```

The convenience of this extension is that `f1` has the desired type, eliminating the need to consistently refer to `f2.f1`.

This has symmetry with normal static arrays, in that an array of unknown size is also written with `[]`.

Of course, this extension only makes sense if the extra data comes at the end of a top-level object, as otherwise we would be overwriting data at subsequent offsets. To avoid undue complication and confusion with initialization of deeply nested arrays, we simply disallow any non-empty initialization except when the structure is the top-level object. For example:

```
struct foo { int x; int y[]; };
struct bar { struct foo z; };

struct foo a = { 1, { 2, 3, 4 } };        // Valid.
struct bar b = { { 1, { 2, 3, 4 } } };    // Invalid.
struct bar c = { { 1, { } } };            // Valid.
struct foo d[1] = { { 1, { 2, 3, 4 } } };  // Invalid.
```

6.2.3 Structures with No Members

GCC permits a C structure to have no members:

```
struct empty {
};
```

The structure has size zero. In C++, empty structures are part of the language. G++ treats empty structures as if they had a single member of type `char`.

6.2.4 Unions with Flexible Array Members

GCC permits a C99 flexible array member (FAM) to be in a union:

```
union with_fam {
  int a;
  int b[];
};
```

If every member of a union is a flexible array member, the size of such a union is zero.

6.2.5 Structures with only Flexible Array Members

GCC permits a C99 flexible array member (FAM) to be alone in a structure:

```
struct only_fam {
  int b[];
};
```

The size of such a structure is zero.

6.2.6 Unnamed Structure and Union Fields

As permitted by ISO C11 and for compatibility with other compilers, GCC allows you to define a structure or union that contains, as fields, structures and unions without names. For example:

```
struct {
  int a;
  union {
    int b;
    float c;
```

```
  };
  int d;
} foo;
```

In this example, you are able to access members of the unnamed union with code like 'foo.b'. Note that only unnamed structs and unions are allowed, you may not have, for example, an unnamed `int`.

You must never create such structures that cause ambiguous field definitions. For example, in this structure:

```
struct {
  int a;
  struct {
    int a;
  };
} foo;
```

it is ambiguous which `a` is being referred to with 'foo.a'. The compiler gives errors for such constructs.

Unless `-fms-extensions` is used, the unnamed field must be a structure or union definition without a tag (for example, 'struct { int a; };'). If `-fms-extensions` is used, the field may also be a definition with a tag such as 'struct foo { int a; };', a reference to a previously defined structure or union such as 'struct foo;', or a reference to a `typedef` name for a previously defined structure or union type.

The option `-fplan9-extensions` enables `-fms-extensions` as well as two other extensions. First, a pointer to a structure is automatically converted to a pointer to an anonymous field for assignments and function calls. For example:

```
struct s1 { int a; };
struct s2 { struct s1; };
extern void f1 (struct s1 *);
void f2 (struct s2 *p) { f1 (p); }
```

In the call to `f1` inside `f2`, the pointer `p` is converted into a pointer to the anonymous field.

Second, when the type of an anonymous field is a `typedef` for a `struct` or `union`, code may refer to the field using the name of the `typedef`.

```
typedef struct { int a; } s1;
struct s2 { s1; };
s1 f1 (struct s2 *p) { return p->s1; }
```

These usages are only permitted when they are not ambiguous.

6.2.7 Cast to a Union Type

A cast to a union type is a C extension not available in C++. It looks just like ordinary casts with the constraint that the type specified is a union type. You can specify the type either with the `union` keyword or with a `typedef` name that refers to a union. The result of a cast to a union is a temporary rvalue of the union type with a member whose type matches that of the operand initialized to the value of the operand. The effect of a cast to a union is similar to a compound literal except that it yields an rvalue like standard casts do. See Section 6.2.10 [Compound Literals], page 614.

Expressions that may be cast to the union type are those whose type matches at least one of the members of the union. Thus, given the following union and variables:

```
union foo { int i; double d; };
```

```
int x;
double y;
union foo z;
```

both `x` and `y` can be cast to type `union foo` and the following assignments

```
  z = (union foo) x;
  z = (union foo) y;
```

are shorthand equivalents of these

```
  z = (union foo) { .i = x };
  z = (union foo) { .d = y };
```

However, `(union foo) FLT_MAX;` is not a valid cast because the union has no member of type `float`.

Using the cast as the right-hand side of an assignment to a variable of union type is equivalent to storing in a member of the union with the same type

```
union foo u;
/* ... */
u = (union foo) x  ≡  u.i = x
u = (union foo) y  ≡  u.d = y
```

You can also use the union cast as a function argument:

```
void hack (union foo);
/* ... */
hack ((union foo) x);
```

6.2.8 Non-Lvalue Arrays May Have Subscripts

In ISO C99, arrays that are not lvalues still decay to pointers, and may be subscripted, although they may not be modified or used after the next sequence point and the unary '`&`' operator may not be applied to them. As an extension, GNU C allows such arrays to be subscripted in C90 mode, though otherwise they do not decay to pointers outside C99 mode. For example, this is valid in GNU C though not valid in C90:

```
struct foo {int a[4];};

struct foo f();

bar (int index)
{
  return f().a[index];
}
```

6.2.9 Non-Constant Initializers

As in standard C++ and ISO C99, the elements of an aggregate initializer for an automatic variable are not required to be constant expressions in GNU C. Here is an example of an initializer with run-time varying elements:

```
foo (float f, float g)
{
  float beat_freqs[2] = { f-g, f+g };
  /* ... */
}
```

6.2.10 Compound Literals

A compound literal looks like a cast of a brace-enclosed aggregate initializer list. Its value is an object of the type specified in the cast, containing the elements specified in the initializer.

Unlike the result of a cast, a compound literal is an lvalue. ISO C99 and later support compound literals. As an extension, GCC supports compound literals also in C90 mode and in C++, although as explained below, the C++ semantics are somewhat different.

Usually, the specified type of a compound literal is a structure. Assume that `struct foo` and `structure` are declared as shown:

```
struct foo {int a; char b[2];} structure;
```

Here is an example of constructing a `struct foo` with a compound literal:

```
structure = ((struct foo) {x + y, 'a', 0});
```

This is equivalent to writing the following:

```
{
  struct foo temp = {x + y, 'a', 0};
  structure = temp;
}
```

You can also construct an array, though this is dangerous in C++, as explained below. If all the elements of the compound literal are (made up of) simple constant expressions suitable for use in initializers of objects of static storage duration, then the compound literal can be coerced to a pointer to its first element and used in such an initializer, as shown here:

```
char **foo = (char *[]) { "x", "y", "z" };
```

As a GNU extension, GCC allows compound literals with a variable size. In this case, only empty initialization is allowed.

```
int n = 4;
char (*p)[n] = &(char[n]){ };
```

Compound literals for scalar types and union types are also allowed. In the following example the variable `i` is initialized to the value `2`, the result of incrementing the unnamed object created by the compound literal.

```
int i = ++(int) { 1 };
```

As a GNU extension, GCC allows initialization of objects with static storage duration by compound literals (which is not possible in ISO C99 because the initializer is not a constant). It is handled as if the object were initialized only with the brace-enclosed list if the types of the compound literal and the object match. The elements of the compound literal must be constant. If the object being initialized has array type of unknown size, the size is determined by the size of the compound literal.

```
static struct foo x = (struct foo) {1, 'a', 'b'};
static int y[] = (int []) {1, 2, 3};
static int z[] = (int [3]) {1};
```

The above lines are equivalent to the following:

```
static struct foo x = {1, 'a', 'b'};
static int y[] = {1, 2, 3};
static int z[] = {1, 0, 0};
```

In C, a compound literal designates an unnamed object with static or automatic storage duration. In C++, a compound literal designates a temporary object that only lives until the end of its full-expression. As a result, well-defined C code that takes the address of a subobject of a compound literal can be undefined in C++, so G++ rejects the conversion of a temporary array to a pointer. For instance, if the array compound literal example above appeared inside a function, any subsequent use of `foo` in C++ would have undefined behavior because the lifetime of the array ends after the declaration of `foo`.

As an optimization, G++ sometimes gives array compound literals longer lifetimes: when the array either appears outside a function or has a `const`-qualified type. If `foo` and its initializer had elements of type `char *const` rather than `char *`, or if `foo` were a global variable, the array would have static storage duration. But it is probably safest just to avoid the use of array compound literals in C++ code.

6.2.11 Designated Initializers

Standard C90 requires the elements of an initializer to appear in a fixed order, the same as the order of the elements in the array or structure being initialized.

In ISO C99 you can give the elements in any order, specifying the array indices or structure field names they apply to, and GNU C allows this as an extension in C90 mode as well. This extension is not implemented in GNU C++.

To specify an array index, write '`[index] =`' before the element value. For example,

```
int a[6] = { [4] = 29, [2] = 15 };
```

is equivalent to

```
int a[6] = { 0, 0, 15, 0, 29, 0 };
```

The index values must be constant expressions, even if the array being initialized is automatic.

An alternative syntax for this that has been obsolete since GCC 2.5 but GCC still accepts is to write '`[index]`' before the element value, with no '`=`'.

To initialize a range of elements to the same value, write '`[first ... last] = value`'. This is a GNU extension. For example,

```
int widths[] = { [0 ... 9] = 1, [10 ... 99] = 2, [100] = 3 };
```

If the value in it has side effects, the side effects happen only once, not for each initialized field by the range initializer.

Note that the length of the array is the highest value specified plus one.

In a structure initializer, specify the name of a field to initialize with '`.fieldname =`' before the element value. For example, given the following structure,

```
struct point { int x, y; };
```

the following initialization

```
struct point p = { .y = yvalue, .x = xvalue };
```

is equivalent to

```
struct point p = { xvalue, yvalue };
```

Another syntax that has the same meaning, obsolete since GCC 2.5, is '`fieldname:`', as shown here:

```
struct point p = { y: yvalue, x: xvalue };
```

Omitted fields are implicitly initialized the same as for objects that have static storage duration.

The '`[index]`' or '`.fieldname`' is known as a *designator*. You can also use a designator (or the obsolete colon syntax) when initializing a union, to specify which element of the union should be used. For example,

```
union foo { int i; double d; };

union foo f = { .d = 4 };
```

converts 4 to a `double` to store it in the union using the second element. By contrast, casting 4 to type `union foo` stores it into the union as the integer `i`, since it is an integer. See Section 6.2.7 [Cast to Union], page 613.

You can combine this technique of naming elements with ordinary C initialization of successive elements. Each initializer element that does not have a designator applies to the next consecutive element of the array or structure. For example,

```
int a[6] = { [1] = v1, v2, [4] = v4 };
```

is equivalent to

```
int a[6] = { 0, v1, v2, 0, v4, 0 };
```

Labeling the elements of an array initializer is especially useful when the indices are characters or belong to an `enum` type. For example:

```
int whitespace[256]
  = { [' '] = 1, ['\t'] = 1, ['\h'] = 1,
      ['\f'] = 1, ['\n'] = 1, ['\r'] = 1 };
```

You can also write a series of '`.fieldname`' and '`[index]`' designators before an '`=`' to specify a nested subobject to initialize; the list is taken relative to the subobject corresponding to the closest surrounding brace pair. For example, with the '`struct point`' declaration above:

```
struct point ptarray[10] = { [2].y = yv2, [2].x = xv2, [0].x = xv0 };
```

If the same field is initialized multiple times, or overlapping fields of a union are initialized, the value from the last initialization is used. When a field of a union is itself a structure, the entire structure from the last field initialized is used. If any previous initializer has side effect, it is unspecified whether the side effect happens or not. Currently, GCC discards the side-effecting initializer expressions and issues a warning.

6.3 Named Address Spaces

As an extension, GNU C supports named address spaces as defined in the N1275 draft of ISO/IEC DTR 18037. Support for named address spaces in GCC will evolve as the draft technical report changes. Calling conventions for any target might also change. At present, only the AVR, M32C, PRU, RL78, and x86 targets support address spaces other than the generic address space.

Address space identifiers may be used exactly like any other C type qualifier (e.g., `const` or `volatile`). See the N1275 document for more details.

6.3.1 AVR Named Address Spaces

On the AVR target, there are several address spaces that can be used in order to put read-only data into the flash memory and access that data by means of the special instructions `LPM` or `ELPM` needed to read from flash.

Devices belonging to `avrtiny` and `avrxmega3` can access flash memory by means of `LD*` instructions because the flash memory is mapped into the RAM address space. There is *no need* for language extensions like `__flash` or attribute Section 6.4.2.3 [`progmem`], page 709. The default linker description files for these devices cater for that feature and `.rodata` stays in flash: The compiler just generates `LD*` instructions, and the linker script adds core specific offsets to all `.rodata` symbols: `0x4000` in the case of `avrtiny` and `0x8000` in the case of `avrxmega3`. See Section 3.20.6 [AVR Options], page 388, for a list of respective devices.

For devices not in `avrtiny` or `avrxmega3`, any data including read-only data is located in RAM (the generic address space) because flash memory is not visible in the RAM address space. In order to locate read-only data in flash memory *and* to generate the right instructions to access this data without using (inline) assembler code, special address spaces are needed.

`__flash`
: The `__flash` qualifier locates data in the `.progmem.data` section. Data is read using the `LPM` instruction. Pointers to this address space are 16 bits wide.

`__flash1`
`__flash2`
`__flash3`
`__flash4`
`__flash5`
: These are 16-bit address spaces locating data in section `.progmem`*N*`.data` where *N* refers to address space `__flash`*N*. The compiler sets the `RAMPZ` segment register appropriately before reading data by means of the `ELPM` instruction.

`__flashx`
: This is a 24-bit flash address space locating data in section `.progmemx.data`. The compiler sets the `RAMPZ` segment register appropriately before reading data by means of the `ELPM` instruction.

`__memx`
: This is a 24-bit address space that linearizes flash and RAM: If the high bit of the address is set, data is read from RAM using the lower two bytes as RAM address. If the high bit of the address is clear, data is read from flash with `RAMPZ` set according to the high byte of the address. See Section 7.13.8 [`__builtin_avr_flash_segment`], page 883.

  Objects in this address space are located in `.progmemx.data`.

Example

```
char my_read (const __flash char ** p)
{
    /* p is a pointer to RAM that points to a pointer to flash.
       The first indirection of p reads that flash pointer
       from RAM and the second indirection reads a char from this
       flash address.  */

    return **p;
}

/* Locate array[] in flash memory */
const __flash int array[] = { 3, 5, 7, 11, 13, 17, 19 };

int i = 1;

int main (void)
{
   /* Return 17 by reading from flash memory */
   return array[array[i]];
}
```

For each named address space supported by avr-gcc there is an equally named but uppercase built-in macro defined. The purpose is to facilitate testing if respective address space support is available or not:

```
#ifdef __FLASH
const __flash int var = 1;

int read_var (void)
{
    return var;
}
#else
#include <avr/pgmspace.h> /* From AVR-LibC */

const int var PROGMEM = 1;

int read_var (void)
{
    return (int) pgm_read_word (&var);
}
#endif /* __FLASH */
```

Notice that attribute Section 6.4.2.3 [progmem], page 709, locates data in flash but accesses to these data read from generic address space, i.e. from RAM, so that you need special accessors like `pgm_read_byte` from AVR-LibC (`https://avrdudes.github.io/avr-libc/avr-libc-user-manual/`) together with attribute `progmem`.

Limitations and Caveats

- Reading across the 64 KiB section boundary of the `__flash` or `__flashN` address spaces is not supported. The only address spaces that support reading across the 64 KiB flash segment boundaries are `__memx` and `__flashx`.
- If you use one of the `__flashN` address spaces you must arrange your linker script to locate the `.progmemN.data` sections according to your needs. For an example, see the avr-gcc wiki (`https://gcc.gnu.org/wiki/avr-gcc#Address_Spaces`)
- Any data or pointers to the non-generic address spaces must be qualified as `const`, i.e. as read-only data. This still applies if the data in one of these address spaces like software version number or calibration lookup table are intended to be changed after load time by, say, a boot loader. In this case the right qualification is `const volatile` so that the compiler must not optimize away known values or insert them as immediates into operands of instructions.
- The following code initializes a variable `pfoo` located in static storage with a 24-bit address:

  ```
  extern const __memx char foo;
  const __memx void *pfoo = &foo;
  ```

- On the reduced Tiny devices like ATtiny40, no address spaces are supported. Just use vanilla C / C++ code without overhead as outlined above. Attribute `progmem` is supported but works differently, see Section 6.4.2.3 [AVR Variable Attributes], page 709.

6.3.2 M32C Named Address Spaces

On the M32C target, with the R8C and M16C CPU variants, variables qualified with `__far` are accessed using 32-bit addresses in order to access memory beyond the first 64 Ki bytes. If `__far` is used with the M32CM or M32C CPU variants, it has no effect.

6.3.3 PRU Named Address Spaces

On the PRU target, variables qualified with `__regio_symbol` are aliases used to access the special I/O CPU registers. They must be declared as `extern` because such variables will not be allocated in any data memory. They must also be marked as `volatile`, and can only be 32-bit integer types. The only names those variables can have are `__R30` and `__R31`, representing respectively the `R30` and `R31` special I/O CPU registers. Hence the following example is the only valid usage of `__regio_symbol`:

```
extern volatile __regio_symbol uint32_t __R30;
extern volatile __regio_symbol uint32_t __R31;
```

6.3.4 RL78 Named Address Spaces

On the RL78 target, variables qualified with `__far` are accessed with 32-bit pointers (20-bit addresses) rather than the default 16-bit addresses. Non-far variables are assumed to appear in the topmost 64 KiB of the address space.

6.3.5 x86 Named Address Spaces

On the x86 target, variables may be declared as being relative to the `%fs` or `%gs` segments.

`__seg_fs`
`__seg_gs`
: The object is accessed with the respective segment override prefix.

  The respective segment base must be set via some method specific to the operating system. Rather than require an expensive system call to retrieve the segment base, these address spaces are not considered to be subspaces of the generic (flat) address space. This means that explicit casts are required to convert pointers between these address spaces and the generic address space. In practice the application should cast to `uintptr_t` and apply the segment base offset that it installed previously.

  The preprocessor symbols `__SEG_FS` and `__SEG_GS` are defined when these address spaces are supported.

6.4 Attributes Specific to GCC

Attributes provide a mechanism to declare additional properties of functions, variables, types, and statements. For example, attributes can be used to control placement of objects in particular memory sections, or to specify properties that can allow the compiler to generate better code or diagnostics, such as declaring that a function never returns. GCC supports a large number of such attributes, which are documented in this section.

GCC provides two different ways to specify attributes: the traditional GNU syntax using '`__attribute__ ((...))`' annotations, and the newer standard C and C++ syntax using '`[[...]]`' with the '`gnu::`' namespace prefix on attribute names. The traditional syntax, described in detail in Section 6.4.7 [Attribute Syntax], page 734, is supported in all non-strict C and C++ language dialects. The standard syntax is supported in C with `-std=c23` or later, in C++ with `-std=c++11` or later, and as an extension in older GNU C and C++ dialects.

6.4.1 Declaring Attributes of Functions

In GNU C and C++, you can use function attributes to specify certain function properties that may help the compiler optimize calls or check code more carefully for correctness. For example, you can use attributes to specify that a function never returns (`noreturn`), returns a value depending only on the values of its arguments (`const`), or has `printf`-style arguments (`format`).

You can also use attributes to control memory placement, code generation options or call/return conventions within the function being annotated. Many of these attributes are target-specific. For example, many targets support attributes for defining interrupt handler functions, which typically must follow special register usage and return conventions. Such attributes are described in the subsection for each target. However, a considerable number of attributes are supported by most, if not all targets. Those are described in the Section 6.4.1.1 [Common Function Attributes], page 622, section.

GCC provides two different ways to specify attributes: the traditional GNU syntax using '`__attribute__ ((...))`' annotations, and the newer standard C and C++ syntax using '`[[...]]`' with the '`gnu::`' prefix on attribute names. Note that the exact rules for placement of attributes in your source code are different depending on which syntax you use. See Section 6.4.7 [Attribute Syntax], page 734, for details.

Compatible attribute specifications on distinct declarations of the same function are merged. An attribute specification that is not compatible with attributes already applied to a declaration of the same function is ignored with a warning.

Some function attributes take one or more arguments that refer to the function's parameters by their positions within the function parameter list. Such attribute arguments are referred to as *positional arguments*. Unless specified otherwise, positional arguments that specify properties of parameters with pointer types can also specify the same properties of the implicit C++ `this` argument in non-static member functions, and of parameters of reference to a pointer type. For ordinary functions, position one refers to the first parameter on the list. In C++ non-static member functions, position one refers to the implicit `this` pointer. The same restrictions and effects apply to function attributes used with ordinary functions or C++ member functions.

GCC also supports attributes on variable declarations (see Section 6.4.2 [Variable Attributes], page 699), labels (see Section 6.4.4 [Label Attributes], page 730), enumerators (see Section 6.4.5 [Enumerator Attributes], page 731), statements (see Section 6.4.6 [Statement Attributes], page 732), types (see Section 6.4.3 [Type Attributes], page 715), and on field declarations (for `tainted_args`).

There is some overlap between the purposes of attributes and pragmas (see Section 6.5 [Pragmas Accepted by GCC], page 738). It has been found convenient to use `__attribute__` to achieve a natural attachment of attributes to their corresponding declarations, whereas `#pragma` is of use for compatibility with other compilers or constructs that do not naturally form part of the grammar.

In addition to the attributes documented here, GCC plugins may provide their own attributes.

6.4.1.1 Common Function Attributes

The following attributes are supported on most targets.

`access (`*`access-mode`*`, `*`ref-index`*`)`
`access (`*`access-mode`*`, `*`ref-index`*`, `*`size-index`*`)`

The `access` attribute enables the detection of invalid or unsafe accesses by functions to which they apply or their callers, as well as write-only accesses to objects that are never read from. Such accesses may be diagnosed by warnings such as `-Wstringop-overflow`, `-Wuninitialized`, `-Wunused`, and others.

The `access` attribute specifies that a pointer or reference argument to the function is accessed according to *access-mode*, which must be one of `read_only`, `read_write`, `write_only`, or `none`. The semantics of these modes are described below.

The argument the attribute applies to is identifed by *ref-index*, which is an integer constant representing its position in the argument list. Argument numbering starts from 1. You can specify multiple `access` attributes to describe the access modes of different arguments, but multiple `access` attributes applying to the same argument are not permitted.

The optional *size-index* denotes the position of a function argument of integer type that specifies the maximum size of the access. The size is the number of elements of the type referenced by *ref-index*, or the number of bytes when the pointer type is `void*`. When no *size-index* argument is specified, the pointer argument must be either null or point to a space that is suitably aligned and large enough for at least one object of the referenced type (this implies that a past-the-end pointer is not a valid argument). The actual size of the access may be less but it must not be more.

The `read_only` access mode specifies that the pointer to which it applies is used to read the referenced object but not write to it. Unless the argument specifying the size of the access denoted by *size-index* is zero, the referenced object must be initialized. The mode implies a stronger guarantee than the `const` qualifier which, when cast away from a pointer, does not prevent the pointed-to object from being modified. Examples of the use of the `read_only` access mode is the argument to the `puts` function, or the second argument to the `memcpy` function.

```
__attribute__ ((access (read_only, 1)))
int puts (const char*);

__attribute__ ((access (read_only, 2, 3)))
void* memcpy (void*, const void*, size_t);
```

The `read_write` access mode applies to arguments of pointer types without the `const` qualifier. It specifies that the pointer to which it applies is used to both read and write the referenced object. Unless the argument specifying the size of the access denoted by *size-index* is zero, the object referenced by the pointer must be initialized. An example of the use of the `read_write` access mode is the first argument to the `strcat` function.

```
__attribute__ ((access (read_write, 1), access (read_only, 2)))
char* strcat (char*, const char*);
```

The `write_only` access mode applies to arguments of pointer types without the `const` qualifier. It specifies that the pointer to which it applies is used to write to the referenced object but not read from it. The object referenced by the pointer need not be initialized. An example of the use of the `write_only` access mode is the first argument to the `strcpy` function, or the first two arguments to the `fgets` function.

```
__attribute__ ((access (write_only, 1), access (read_only, 2)))
char* strcpy (char*, const char*);

__attribute__ ((access (write_only, 1, 2), access (read_write, 3)))
int fgets (char*, int, FILE*);
```

The access mode `none` specifies that the pointer argument to which it applies is not used to access the referenced object at all. Unless the pointer is null, the pointed-to object must exist and have at least the size as denoted by the *size-index* argument. When the optional *size-index* argument is omitted for an argument of `void*` type, the actual pointer argument is ignored. The referenced object need not be initialized. The mode is intended to be used as a means to help validate the expected object size, for example in functions that call `__builtin_object_size`. See Section 7.10 [Object Size Checking], page 861.

Note that the `access` attribute merely specifies how an object referenced by the pointer argument can be accessed; it does not imply that an access **will** happen. Also, the `access` attribute does not imply the attribute `nonnull` nor the attribute `nonnull_if_nonzero`; it may be appropriate to add both attributes at the declaration of a function that unconditionally manipulates a buffer via a pointer argument. See the `nonnull` or `nonnull_if_nonzero` function attributes, documented later in this section, for more information and caveats.

`alias ("`*`target`*`")`

The `alias` attribute causes the declaration to be emitted as an alias for another symbol, which must have been previously declared with the same type, and for variables, also the same size and alignment. Declaring an alias with a different type than the target is undefined and may be diagnosed. As an example, the following declarations:

```
void __f () { /* Do something. */; }
void f () __attribute__ ((weak, alias ("__f")));
```

define '`f`' to be a weak alias for '`__f`'. In C++, the mangled name for the target must be used. It is an error if '`__f`' is not defined in the same translation unit.

This attribute requires assembler and object file support, and may not be available on all targets.

`aligned`
`aligned (`*`alignment`*`)`

The `aligned` attribute specifies a minimum alignment for the first instruction of the function, measured in bytes. When specified, *alignment* must be an integer constant power of 2. Specifying no *alignment* argument implies the ideal alignment for the target. The `__alignof__` operator can be used to determine what that is (see Section 6.12.9 [Alignment], page 820). The attribute has no effect when a definition for the function is not provided in the same translation unit.

The attribute cannot be used to decrease the alignment of a function previously declared with a more restrictive alignment; only to increase it. Attempts to do otherwise are diagnosed. Some targets specify a minimum default alignment for functions that is greater than 1. On such targets, specifying a less restrictive alignment is silently ignored. Using the attribute overrides the effect of the `-falign-functions` (see Section 3.12 [Optimize Options], page 194) option for this function.

Note that the effectiveness of `aligned` attributes may be limited by inherent limitations in the system linker and/or object file format. On some systems, the linker is only able to arrange for functions to be aligned up to a certain maximum alignment. (For some linkers, the maximum supported alignment may be very very small.) See your linker documentation for further information.

The `aligned` attribute can also be used for variables and fields (see Section 6.4.2 [Variable Attributes], page 699.)

`alloc_align (`*`position`*`)`

The `alloc_align` attribute may be applied to a function that returns a pointer and takes at least one argument of an integer or enumerated type. It indicates that the returned pointer is aligned on a boundary given by the function argument at *position*. Meaningful alignments are powers of 2 greater than one. GCC uses this information to improve pointer alignment analysis.

The function parameter denoting the allocated alignment is specified by one constant integer argument whose number is the argument of the attribute. Argument numbering starts at one.

For instance,

```
void* my_memalign (size_t, size_t) __attribute__ ((alloc_align (1)));
```

declares that `my_memalign` returns memory with minimum alignment given by parameter 1.

`alloc_size (`*`position`*`)`
`alloc_size (`*`position-1`*`, `*`position-2`*`)`

The `alloc_size` attribute may be applied to a function that returns a pointer and takes at least one argument of an integer or enumerated type. It indicates that the returned pointer points to memory whose size is given by the function argument at *position-1*, or by the product of the arguments at *position-1* and *position-2*. Meaningful sizes are positive values less than `PTRDIFF_MAX`. GCC uses this information to improve the results of `__builtin_object_size`.

The function parameter(s) denoting the allocated size are specified by one or two integer arguments supplied to the attribute. The allocated size is either the value of the single function argument specified or the product of the two function arguments specified. Argument numbering starts at one for ordinary functions, and at two for C++ non-static member functions.

For instance,

```
void* my_calloc (size_t, size_t) __attribute__ ((alloc_size (1, 2)));
```

```
void* my_realloc (void*, size_t) __attribute__ ((alloc_size (2)));
```

declares that `my_calloc` returns memory of the size given by the product of parameter 1 and 2 and that `my_realloc` returns memory of the size given by parameter 2.

`always_inline`

Generally, functions are not inlined unless optimization is specified. For functions declared inline, this attribute inlines the function independent of any restrictions that otherwise apply to inlining. Failure to inline such a function is diagnosed as an error. Note that if such a function is called indirectly the compiler may or may not inline it depending on optimization level and a failure to inline an indirect call may or may not be diagnosed.

If you need to use the inlined function in multiple translation units, you should put the `always_inline` attribute on a function definition in a header file that is included in all translation units where the function is used. Link-time optimization can inline functions across translation units, but only if an optimization level that normally enables inlining is additionally specified.

`artificial`

This attribute is useful for small inline wrappers that if possible should appear during debugging as a unit. Depending on the debug info format it either means marking the function as artificial or using the caller location for all instructions within the inlined body.

`assume_aligned (`*`alignment`*`)`
`assume_aligned (`*`alignment, offset`*`)`

The `assume_aligned` attribute may be applied to a function that returns a pointer. It indicates that the returned pointer is aligned on a boundary given by *alignment*. If the attribute has two arguments, the second argument is misalignment *offset*. Meaningful values of *alignment* are powers of 2 greater than one. Meaningful values of *offset* are greater than zero and less than *alignment*.

For instance

```
void* my_alloc1 (size_t) __attribute__((assume_aligned (16)));
void* my_alloc2 (size_t) __attribute__((assume_aligned (32, 8)));
```

declares that `my_alloc1` returns 16-byte aligned pointers and that `my_alloc2` returns a pointer whose value modulo 32 is equal to 8.

`btf_decl_tag`

The `btf_decl_tag` attribute may be used to associate function declarations with arbitrary strings by recording those strings in DWARF and/or BTF information in the same way that it is used for variables. See Section 6.4.2.1 [Common Variable Attributes], page 699.

`cold` The `cold` attribute on functions is used to inform the compiler that the function is unlikely to be executed. The function is optimized for size rather than speed and on many targets it is placed into a special subsection of the text section so all cold functions appear close together, improving code locality of non-cold parts of program. The paths leading to calls of cold functions within code are marked as unlikely by the branch prediction mechanism. It is thus useful to mark functions used to handle unlikely conditions, such as `perror`, as cold to improve optimization of hot functions that do call marked functions in rare occasions. In C++, the `cold` attribute can be applied to types with the effect of being propagated to member functions. See Section 8.7 [C++ Attributes], page 1067.

When profile feedback is available, via `-fprofile-use`, cold functions are automatically detected and this attribute is ignored.

`const` Calls to functions whose return value is not affected by changes to the observable state of the program and that have no observable effects on such state other than to return a value may lend themselves to optimizations such as common subexpression elimination. Declaring such functions with the `const` attribute allows GCC to avoid emitting some calls in repeated invocations of the function with the same argument values.

For example,

```
int square (int) __attribute__ ((const));
```

tells GCC that subsequent calls to function `square` with the same argument value can be replaced by the result of the first call regardless of the statements in between.

The `const` attribute prohibits a function from reading objects that affect its return value between successive invocations. However, functions declared with the attribute can safely read objects that do not change their return value, such as non-volatile constants.

The `const` attribute imposes greater restrictions on a function's definition than the similar `pure` attribute. Declaring the same function with both the `const` and the `pure` attribute is diagnosed. Because a const function cannot have any observable side effects it does not make sense for it to return `void`. Declaring such a function is diagnosed.

Note that a function that has pointer arguments and examines the data pointed to must *not* be declared `const` if the pointed-to data might change between successive invocations of the function. In general, since a function cannot distinguish data that might change from data that cannot, const functions should never take pointer or, in C++, reference arguments. Likewise, a function that calls a non-const function usually must not be const itself.

`constructor`
`destructor`
`constructor (`*priority*`)`
`destructor (`*priority*`)`

The `constructor` attribute causes the function to be called automatically before execution enters `main ()`. Similarly, the `destructor` attribute causes the function to be called automatically after `main ()` completes or `exit ()` is called. Functions with these attributes are useful for initializing data that is used implicitly during the execution of the program.

On most targets the attributes also accept an integer argument to specify a priority to control the order in which constructor and destructor functions are run. The *priority* argument is a constant integral expression bounded between 101 and 65535 inclusive; priorities 0-100 are reserved for use by the compiler and its runtime libraries. A constructor with a smaller priority number runs before a constructor with a larger priority number; the opposite relationship holds for destructors. So, if you have a constructor that allocates a resource and a destructor that deallocates the same resource, both functions typically have the same priority.

The order in which constructors for C++ objects with static storage duration are invoked relative to functions decorated with attribute `constructor` is normally unspecified. You can use attribute `init_priority` (see Section 8.7 [C++ Attributes], page 1067) on the declarations of namespace-scope C++ objects to impose a specific ordering; the *priority* for the `init_priority` attribute has the same effect as the *priority* for the `constructor` attribute.

Using the argument form of the `constructor` and `destructor` attributes on targets where the feature is not supported is rejected with an error. Only a few targets (typically those not using ELF object format, or the GNU linker) reject this usage.

`copy`
`copy (`*`function`*`)`

The `copy` attribute applies the set of attributes with which *function* has been declared to the declaration of the function to which the attribute is applied. The attribute is designed for libraries that define aliases or function resolvers that are expected to specify the same set of attributes as their targets. The `copy` attribute can be used with functions, variables, or types. However, the kind of symbol to which the attribute is applied (either function or variable) must match the kind of symbol to which the argument refers. The `copy` attribute copies only syntactic and semantic attributes but not attributes that affect a symbol's linkage or visibility such as `alias`, `visibility`, or `weak`. The `deprecated` and `target_clones` attribute are also not copied. See Section 6.4.3.1 [Common Type Attributes], page 715. See Section 6.4.2.1 [Common Variable Attributes], page 699.

For example, the *StrongAlias* macro below makes use of the `alias` and `copy` attributes to define an alias named *alloc* for function *allocate* declared with attributes *alloc_size*, *malloc*, and *nothrow*. Thanks to the `__typeof__` operator the alias has the same type as the target function. As a result of the `copy` attribute the alias also shares the same attributes as the target.

```
#define StrongAlias(TargetFunc, AliasDecl)  \
  extern __typeof__ (TargetFunc) AliasDecl  \
    __attribute__ ((alias (#TargetFunc), copy (TargetFunc)));

extern __attribute__ ((alloc_size (1), malloc, nothrow))
  void* allocate (size_t);
StrongAlias (allocate, alloc);
```

`deprecated`
`deprecated (`*`msg`*`)`

The `deprecated` attribute results in a warning if the function is used anywhere in the source file. This is useful when identifying functions that are expected to be removed in a future version of a program. The warning also includes the location of the declaration of the deprecated function, to enable users to easily find further information about why the function is deprecated, or what they should do instead. Note that the warnings only occurs for uses:

```
int old_fn () __attribute__ ((deprecated));
int old_fn ();
int (*fn_ptr)() = old_fn;
```

results in a warning on line 3 but not line 2. The optional *msg* argument, which must be a string, is printed in the warning if present.

The `deprecated` attribute can also be used for variables and types (see Section 6.4.2 [Variable Attributes], page 699, see Section 6.4.3 [Type Attributes], page 715.)

The message attached to the attribute is affected by the setting of the `-fmessage-length` option.

`error ("`*message*`")`
`warning ("`*message*`")`

If the `error` or `warning` attribute is used on a function declaration and a call to such a function is not eliminated through dead code elimination or other optimizations, an error or warning (respectively) that includes *message* is diagnosed. This is useful for compile-time checking, especially together with `__builtin_constant_p` and inline functions where checking the inline function arguments is not possible through `extern char [(condition) ? 1 : -1];` tricks.

While it is possible to leave the function undefined and thus invoke a link failure (to define the function with a message in `.gnu.warning*` section), when using these attributes the problem is diagnosed earlier and with exact location of the call even in presence of inline functions or when not emitting debugging information.

`expected_throw`

This attribute, attached to a function, tells the compiler the function is more likely to raise or propagate an exception than to return, loop forever, or terminate the program.

This hint is mostly ignored by the compiler. The only effect is when it's applied to `noreturn` functions and '`-fharden-control-flow-redundancy`' is enabled, and '`-fhardcfr-check-noreturn-calls=not-always`' is not overridden.

`externally_visible`

This attribute, attached to a global variable or function, nullifies the effect of the `-fwhole-program` command-line option, so the object remains visible outside the current compilation unit.

If `-fwhole-program` is used together with `-flto` and `gold` is used as the linker plugin, `externally_visible` attributes are automatically added to functions (not variable yet due to a current `gold` issue) that are accessed outside of LTO objects according to resolution file produced by `gold`. For other linkers that cannot generate resolution file, explicit `externally_visible` attributes are still necessary.

`fd_arg`
`fd_arg (N)`

The `fd_arg` attribute may be applied to a function that takes an open file descriptor at referenced argument *N*.

It indicates that the passed filedescriptor must not have been closed. Therefore, when the analyzer is enabled with `-fanalyzer`, the analyzer may emit a `-Wanalyzer-fd-use-after-close` diagnostic if it detects a code path in which a function with this attribute is called with a closed file descriptor.

The attribute also indicates that the file descriptor must have been checked for validity before usage. Therefore, analyzer may emit `-Wanalyzer-fd-use-without-check` diagnostic if it detects a code path in which a function with this attribute is called with a file descriptor that has not been checked for validity.

`fd_arg_read`
`fd_arg_read (N)`

The `fd_arg_read` is identical to `fd_arg`, but with the additional requirement that it might read from the file descriptor, and thus, the file descriptor must not have been opened as write-only.

The analyzer may emit a `-Wanalyzer-access-mode-mismatch` diagnostic if it detects a code path in which a function with this attribute is called on a file descriptor opened with `O_WRONLY`.

`fd_arg_write`
`fd_arg_write (N)`

The `fd_arg_write` is identical to `fd_arg_read` except that the analyzer may emit a `-Wanalyzer-access-mode-mismatch` diagnostic if it detects a code path in which a function with this attribute is called on a file descriptor opened with `O_RDONLY`.

`flatten`

Generally, inlining into a function is limited. For a function marked with this attribute, every call inside this function is inlined including the calls such inlining introduces to the function (but not recursive calls to the function itself), if possible. Functions declared with attribute `noinline` and similar are not inlined. Whether the function itself is considered for inlining depends on its size and the current inlining parameters.

`format (archetype, string-index, first-to-check)`

The `format` attribute specifies that a function takes `printf`, `scanf`, `strftime` or `strfmon` style arguments that should be type-checked against a format string. For example, the declaration:

```
extern int
my_printf (void *my_object, const char *my_format, ...)
      __attribute__ ((format (printf, 2, 3)));
```

causes the compiler to check the arguments in calls to `my_printf` for consistency with the `printf` style format string argument `my_format`.

The parameter *archetype* determines how the format string is interpreted. Valid archetypes include `printf`, `scanf`, `strftime`, `gnu_printf`, `gnu_scanf`, `gnu_strftime` or `strfmon`. (You can also use `__printf__`, `__scanf__`, `__strftime_`

_ or `__strfmon__`.) *archetype* values such as `printf` refer to the formats accepted by the system's C runtime library, while values prefixed with '`gnu_`' always refer to the formats accepted by the GNU C Library.

On MinGW and Microsoft Windows targets, `ms_printf`, `ms_scanf`, and `ms_strftime` are also present. Values prefixed with '`ms_`' refer to the formats accepted by the `msvcrt.dll` library.

Solaris targets also support the `cmn_err` (or `__cmn_err__`) archetype. `cmn_err` accepts a subset of the standard `printf` conversions, and the two-argument `%b` conversion for displaying bit-fields. See the Solaris man page for `cmn_err` for more information.

Darwin targets also support the `CFString` (or `__CFString__`) archetype in the `format` attribute. Declarations with this archetype are parsed for correct syntax and argument types. However, parsing of the format string itself and validating arguments against it in calls to such functions is currently not performed.

For Objective-C dialects, `NSString` (or `__NSString__`) is recognized in the same context. Declarations including these format attributes are parsed for correct syntax, however the result of checking of such format strings is not yet defined, and is not carried out by this version of the compiler.

The parameter *string-index* specifies which argument is the format string argument (starting from 1), while *first-to-check* is the number of the first argument to check against the format string. For functions where the arguments are not available to be checked (such as `vprintf`), specify the third parameter as zero. In this case the compiler only checks the format string for consistency. For `strftime` formats, the third parameter is required to be zero. Since non-static C++ methods have an implicit `this` argument, the arguments of such methods should be counted from two, not one, when giving values for *string-index* and *first-to-check*.

In the example above, the format string (`my_format`) is the second argument of the function `my_print`, and the arguments to check start with the third argument, so the correct parameters for the format attribute are 2 and 3.

The `format` attribute allows you to identify your own functions that take format strings as arguments, so that GCC can check the calls to these functions for errors. The compiler always (unless `-ffreestanding` or `-fno-builtin` is used) checks formats for the standard library functions `printf`, `fprintf`, `sprintf`, `scanf`, `fscanf`, `sscanf`, `strftime`, `vprintf`, `vfprintf` and `vsprintf` whenever such warnings are requested (using `-Wformat`), so there is no need to modify the header file `stdio.h`. In C99 mode, the functions `snprintf`, `vsnprintf`, `vscanf`, `vfscanf` and `vsscanf` are also checked. Except in strictly conforming C standard modes, the X/Open function `strfmon` is also checked as are `printf_unlocked` and `fprintf_unlocked`. See Section 3.4 [Options Controlling C Dialect], page 45.

`format_arg (`*`string-index`*`)`

The `format_arg` attribute specifies that a function takes one or more format strings for a `printf`, `scanf`, `strftime` or `strfmon` style function and modifies it (for example, to translate it into another language), so the result can be passed to a printf, scanf, strftime or strfmon style function (with the remaining arguments to the format function the same as they would have been for the unmodified string). Multiple format_arg attributes may be applied to the same function, each designating a distinct parameter as a format string. For example, the declaration:

```
extern char *
my_dgettext (char *my_domain, const char *my_format)
      __attribute__ ((format_arg (2)));
```

causes the compiler to check the arguments in calls to a printf, scanf, strftime or strfmon type function, whose format string argument is a call to the my_dgettext function, for consistency with the format string argument my_format. If the format_arg attribute had not been specified, all the compiler could tell in such calls to format functions would be that the format string argument is not constant; this would generate a warning when -Wformat-nonliteral is used, but the calls could not be checked without the attribute.

In calls to a function declared with more than one format_arg attribute, each with a distinct argument value, the corresponding actual function arguments are checked against all format strings designated by the attributes. This capability is designed to support the GNU ngettext family of functions.

The parameter *string-index* specifies which argument is the format string argument (starting from one). Since non-static C++ methods have an implicit this argument, the arguments of such methods should be counted from two.

The format_arg attribute allows you to identify your own functions that modify format strings, so that GCC can check the calls to printf, scanf, strftime or strfmon type function whose operands are a call to one of your own function. The compiler always treats gettext, dgettext, and dcgettext in this manner except when strict ISO C support is requested by -ansi or an appropriate -std option, or -ffreestanding or -fno-builtin is used. See Section 3.4 [Options Controlling C Dialect], page 45.

For Objective-C dialects, the format_arg attribute may refer to an NSString reference for compatibility with the format attribute above.

Similarly, on Darwin targets CFStringRefs (defined by the CoreFoundation headers) may also be used as format arguments. Note that the relevant headers are only likely to be available on Darwin (OSX) installations. On such installations, the XCode and system documentation provide descriptions of CFString, CFStringRefs and associated functions.

gnu_inline

This attribute should be used with a function that is also declared with the inline keyword. It directs GCC to treat the function as if it were defined in gnu90 mode even when compiling in C99 or gnu99 mode.

If the function is declared extern, then this definition of the function is used only for inlining. In no case is the function compiled as a standalone function, not even if you take its address explicitly. Such an address becomes an external reference, as if you had only declared the function, and had not defined it. This has almost the effect of a macro. The way to use this is to put a function definition in a header file with this attribute, and put another copy of the function, without `extern`, in a library file. The definition in the header file causes most calls to the function to be inlined. If any uses of the function remain, they refer to the single copy in the library. Note that the two definitions of the functions need not be precisely the same, although if they do not have the same effect your program may behave oddly.

In C, if the function is neither `extern` nor `static`, then the function is compiled as a standalone function, as well as being inlined where possible.

This is how GCC traditionally handled functions declared `inline`. Since ISO C99 specifies a different semantics for `inline`, this function attribute is provided as a transition measure and as a useful feature in its own right. This attribute is available in GCC 4.1.3 and later. It is available if either of the preprocessor macros `__GNUC_GNU_INLINE__` or `__GNUC_STDC_INLINE__` are defined. See Section 6.9 [An Inline Function is As Fast As a Macro], page 750.

In C++, this attribute does not depend on `extern` in any way, but it still requires the `inline` keyword to enable its special behavior.

`hot` The `hot` attribute on a function is used to inform the compiler that the function is a hot spot of the compiled program. The function is optimized more aggressively and on many targets it is placed into a special subsection of the text section so all hot functions appear close together, improving locality. In C++, the `hot` attribute can be applied to types with the effect of being propagated to member functions. See Section 8.7 [C++ Attributes], page 1067.

When profile feedback is available, via `-fprofile-use`, hot functions are automatically detected and this attribute is ignored.

`ifunc ("`*`resolver`*`")`

The `ifunc` attribute is used to mark a function as an indirect function using the STT_GNU_IFUNC symbol type extension to the ELF standard. This allows the resolution of the symbol value to be determined dynamically at load time, and an optimized version of the routine to be selected for the particular processor or other system characteristics determined then. To use this attribute, first define the implementation functions available, and a resolver function that returns a pointer to the selected implementation function. The implementation functions' declarations must match the API of the function being implemented. The resolver should be declared to be a function taking no arguments and returning a pointer to a function of the same type as the implementation. For example:

```
void *my_memcpy (void *dst, const void *src, size_t len)
{
  ...
  return dst;
}

static void * (*resolve_memcpy (void))(void *, const void *, size_t)
{
  return my_memcpy; // we will just always select this routine
}
```

The exported header file declaring the function the user calls would contain:

```
extern void *memcpy (void *, const void *, size_t);
```

allowing the user to call `memcpy` as a regular function, unaware of the actual implementation. Finally, the indirect function needs to be defined in the same translation unit as the resolver function:

```
void *memcpy (void *, const void *, size_t)
     __attribute__ ((ifunc ("resolve_memcpy")));
```

In C++, the `ifunc` attribute takes a string that is the mangled name of the resolver function. A C++ resolver for a non-static member function of class `C` should be declared to return a pointer to a non-member function taking pointer to `C` as the first argument, followed by the same arguments as of the implementation function. G++ checks the signatures of the two functions and issues a `-Wattribute-alias` warning for mismatches. To suppress a warning for the necessary cast from a pointer to the implementation member function to the type of the corresponding non-member function use the `-Wno-pmf-conversions` option. For example:

```
class S
{
private:
  int debug_impl (int);
  int optimized_impl (int);

  typedef int Func (S*, int);

  static Func* resolver ();
public:

  int interface (int);
};

int S::debug_impl (int) { /* ... */ }
int S::optimized_impl (int) { /* ... */ }

S::Func* S::resolver ()
{
  int (S::*pimpl) (int)
    = getenv ("DEBUG") ? &S::debug_impl : &S::optimized_impl;

  // Cast triggers -Wno-pmf-conversions.
  return reinterpret_cast<Func*>(pimpl);
}

int S::interface (int) __attribute__ ((ifunc ("_ZN1S8resolverEv")));
```

Indirect functions cannot be weak. Binutils version 2.20.1 or higher and GNU C Library version 2.11.1 are required to use this feature.

`interrupt`
`interrupt_handler`

Many GCC back ends support attributes to indicate that a function is an interrupt handler, which tells the compiler to generate function entry and exit sequences that differ from those from regular functions. The exact syntax and behavior are target-specific; refer to the following subsections for details.

`leaf`
: Calls to external functions with this attribute must return to the current compilation unit only by return or by exception handling. In particular, a leaf function is not allowed to invoke callback functions passed to it from the current compilation unit, directly call functions exported by the unit, or `longjmp` into the unit. Leaf functions might still call functions from other compilation units and thus they are not necessarily leaf in the sense that they contain no function calls at all.

  The attribute is intended for library functions to improve dataflow analysis. The compiler takes the hint that any data not escaping the current compilation unit cannot be used or modified by the leaf function. For example, the `sin` function is a leaf function, but `qsort` is not.

  Note that leaf functions might indirectly run a signal handler defined in the current compilation unit that uses static variables. Similarly, when lazy symbol resolution is in effect, leaf functions might invoke indirect functions whose resolver function or implementation function is defined in the current compilation unit and uses static variables. There is no standard-compliant way to write such a signal handler, resolver function, or implementation function, and the best that you can do is to remove the `leaf` attribute or mark all such static variables `volatile`. Lastly, for ELF-based systems that support symbol interposition, care should be taken that functions defined in the current compilation unit do not unexpectedly interpose other symbols based on the defined standards mode and defined feature test macros; otherwise an inadvertent callback would be added.

  The attribute has no effect on functions defined within the current compilation unit. This is to allow easy merging of multiple compilation units into one, for example, by using the link-time optimization. For this reason the attribute is not allowed on types to annotate indirect calls.

`malloc`

`malloc (`*`deallocator`*`)`
`malloc (`*`deallocator`*`, `*`ptr-index`*`)`
: Attribute `malloc` indicates that a function is `malloc`-like, i.e., that the pointer *P* returned by the function cannot alias any other pointer valid when the function returns, and moreover no pointers to valid objects occur in any storage addressed by *P*. In addition, GCC predicts that a function with the attribute returns non-null in most cases.

  Independently, the form of the attribute with one or two arguments associates `deallocator` as a suitable deallocation function for pointers returned from the `malloc`-like function. *ptr-index* denotes the positional argument to which when the pointer is passed in calls to `deallocator` has the effect of deallocating it.

  Using the attribute with no arguments is designed to improve optimization by relying on the aliasing property it implies. Functions like `malloc` and `calloc` have this property because they return a pointer to uninitialized or zeroed-out, newly obtained storage. However, functions like `realloc` do not have this property, as they may return pointers to storage containing pointers to existing objects. Additionally, since all such functions are assumed to return null only infrequently, callers can be optimized based on that assumption.

Associating a function with a *deallocator* helps detect calls to mismatched allocation and deallocation functions and diagnose them under the control of options such as `-Wmismatched-dealloc`. It also makes it possible to diagnose attempts to deallocate objects that were not allocated dynamically, by `-Wfree-nonheap-object`. To indicate that an allocation function both satisfies the nonaliasing property and has a deallocator associated with it, both the plain form of the attribute and the one with the *deallocator* argument must be used. The same function can be both an allocator and a deallocator. Since inlining one of the associated functions but not the other could result in apparent mismatches, this form of attribute `malloc` is not accepted on inline functions. For the same reason, using the attribute prevents both the allocation and deallocation functions from being expanded inline.

For example, besides stating that the functions return pointers that do not alias any others, the following declarations make `fclose` a suitable deallocator for pointers returned from all functions except `popen`, and `pclose` as the only suitable deallocator for pointers returned from `popen`. The deallocator functions must be declared before they can be referenced in the attribute.

```
int fclose (FILE*);
int pclose (FILE*);

__attribute__ ((malloc, malloc (fclose, 1)))
  FILE* fdopen (int, const char*);
__attribute__ ((malloc, malloc (fclose, 1)))
  FILE* fopen (const char*, const char*);
__attribute__ ((malloc, malloc (fclose, 1)))
  FILE* fmemopen(void *, size_t, const char *);
__attribute__ ((malloc, malloc (pclose, 1)))
  FILE* popen (const char*, const char*);
__attribute__ ((malloc, malloc (fclose, 1)))
  FILE* tmpfile (void);
```

The warnings guarded by `-fanalyzer` respect allocation and deallocation pairs marked with the `malloc`. In particular:

- The analyzer emits a `-Wanalyzer-mismatching-deallocation` diagnostic if there is an execution path in which the result of an allocation call is passed to a different deallocator.
- The analyzer emits a `-Wanalyzer-double-free` diagnostic if there is an execution path in which a value is passed more than once to a deallocation call.
- The analyzer considers the possibility that an allocation function could fail and return null. If there are execution paths in which an unchecked result of an allocation call is dereferenced or passed to a function requiring a non-null argument, it emits `-Wanalyzer-possible-null-dereference` and `-Wanalyzer-possible-null-argument` diagnostics. If the allocator always returns non-null, use `__attribute__ ((returns_nonnull))` to suppress these warnings. For example:

  ```
  char *xstrdup (const char *)
  ```

```
__attribute__((malloc (free), returns_nonnull));
```

- The analyzer emits a `-Wanalyzer-use-after-free` diagnostic if there is an execution path in which the memory passed by pointer to a deallocation call is used after the deallocation.
- The analyzer emits a `-Wanalyzer-malloc-leak` diagnostic if there is an execution path in which the result of an allocation call is leaked (without being passed to the deallocation function).
- The analyzer emits a `-Wanalyzer-free-of-non-heap` diagnostic if a deallocation function is used on a global or on-stack variable.

The analyzer assumes that deallocators can gracefully handle the null pointer. If this is not the case, the deallocator can be marked with `__attribute__ ((nonnull))` so that `-fanalyzer` can emit a `-Wanalyzer-possible-null-argument` diagnostic for code paths in which the deallocator is called with null.

`no_icf` This function attribute prevents a functions from being merged with another semantically equivalent function.

`no_instrument_function`

If any of `-finstrument-functions`, `-p`, or `-pg` are given, profiling function calls are generated at entry and exit of most user-compiled functions. Functions with this attribute are not so instrumented.

`no_profile_instrument_function`

The `no_profile_instrument_function` attribute on functions is used to inform the compiler that it should not process any profile feedback based optimization code instrumentation.

`no_reorder`

Do not reorder functions or variables marked `no_reorder` against each other or top level assembler statements the executable. The actual order in the program will depend on the linker command line. Static variables marked like this are also not removed. This has a similar effect as the `-fno-toplevel-reorder` option, but only applies to the marked symbols.

`no_sanitize ("`*`sanitize_option`*`")`

The `no_sanitize` attribute on functions is used to inform the compiler that it should not do sanitization of any option mentioned in *sanitize_option*. A list of values acceptable by the `-fsanitize` option can be provided.

```
void __attribute__ ((no_sanitize ("alignment", "object-size")))
f () { /* Do something. */; }
void __attribute__ ((no_sanitize ("alignment,object-size")))
g () { /* Do something. */; }
```

`no_sanitize_address`
`no_address_safety_analysis`

The `no_sanitize_address` attribute on functions is used to inform the compiler that it should not instrument memory accesses in the function when compiling with the `-fsanitize=address` option. The `no_address_safety_analysis` is a deprecated alias of the `no_sanitize_address` attribute, new code should use `no_sanitize_address`.

`no_sanitize_thread`
: The `no_sanitize_thread` attribute on functions is used to inform the compiler that it should not instrument memory accesses in the function when compiling with the `-fsanitize=thread` option.

`no_sanitize_undefined`
: The `no_sanitize_undefined` attribute on functions is used to inform the compiler that it should not check for undefined behavior in the function when compiling with the `-fsanitize=undefined` option.

`no_sanitize_coverage`
: The `no_sanitize_coverage` attribute on functions is used to inform the compiler that it should not do coverage-guided fuzzing code instrumentation (`-fsanitize-coverage`).

`no_split_stack`
: If `-fsplit-stack` is given, functions have a small prologue which decides whether to split the stack. Functions with the `no_split_stack` attribute do not have that prologue, and thus may run with only a small amount of stack space available.

`no_stack_limit`
: This attribute locally overrides the `-fstack-limit-register` and `-fstack-limit-symbol` command-line options; it has the effect of disabling stack limit checking in the function it applies to.

`no_stack_protector`
: This attribute prevents stack protection code for the function.

`noclone`
: This function attribute prevents a function from being considered for cloning—a mechanism that produces specialized copies of functions and which is (currently) performed by interprocedural constant propagation.

`noinline`
: This function attribute prevents a function from being considered for inlining. It also disables some other interprocedural optimizations; it's preferable to use the more comprehensive `noipa` attribute instead if that is your goal.

  Even if a function is declared with the `noinline` attribute, there are optimizations other than inlining that can cause calls to be optimized away if it does not have side effects, although the function call is live. To keep such calls from being optimized away, put

```
asm ("");
```

  (see Section 6.11.2 [Extended Asm], page 754) in the called function, to serve as a special side effect.

`noipa`
: Disable interprocedural optimizations between the function with this attribute and its callers, as if the body of the function is not available when optimizing callers and the callers are unavailable when optimizing the body. This attribute implies `noinline`, `noclone` and `no_icf` attributes. However, this attribute is not equivalent to a combination of other attributes, because its purpose is to suppress existing and future optimizations employing interprocedural analysis, including those that do not have an attribute suitable for disabling them individually.

`nonnull`
`nonnull (arg-index, ...)`

The `nonnull` attribute may be applied to a function that takes at least one argument of a pointer type. It indicates that the referenced arguments must be non-null pointers. For instance, the declaration:

```
extern void *
my_memcpy (void *dest, const void *src, size_t len)
        __attribute__((nonnull (1, 2)));
```

informs the compiler that, in calls to `my_memcpy`, arguments *dest* and *src* must be non-null.

The attribute has an effect both on functions calls and function definitions.

For function calls:

- If the compiler determines that a null pointer is passed in an argument slot marked as non-null, and the `-Wnonnull` option is enabled, a warning is issued. See Section 3.9 [Warning Options], page 100.
- The `-fisolate-erroneous-paths-attribute` option can be specified to have GCC transform calls with null arguments to non-null functions into traps. See Section 3.12 [Optimize Options], page 194.
- The compiler may also perform optimizations based on the knowledge that certain function arguments cannot be null. These optimizations can be disabled by the `-fno-delete-null-pointer-checks` option. See Section 3.12 [Optimize Options], page 194.

For function definitions:

- If the compiler determines that a function parameter that is marked with nonnull is compared with null, and `-Wnonnull-compare` option is enabled, a warning is issued. See Section 3.9 [Warning Options], page 100.
- The compiler may also perform optimizations based on the knowledge that `nonnull` parameters cannot be null. This can currently not be disabled other than by removing the nonnull attribute.

If no *arg-index* is given to the `nonnull` attribute, all pointer arguments are marked as non-null. To illustrate, the following declaration is equivalent to the previous example:

```
extern void *
my_memcpy (void *dest, const void *src, size_t len)
        __attribute__((nonnull));
```

`nonnull_if_nonzero`
`nonnull_if_nonzero (arg-index, arg2-index)`
`nonnull_if_nonzero (arg-index, arg2-index, arg3-index)`

The `nonnull_if_nonzero` attribute is a conditional version of the `nonnull` attribute. It has two or three arguments, the first argument shall be argument index of a pointer argument which must be in some cases non-null and the second argument shall be argument index of an integral argument (other than boolean). If the integral argument is zero, the pointer argument can be null, if it is non-zero, the pointer argument must not be null. If three arguments are provided, the third argument shall be argument index of another integral argument (other than boolean) and the pointer argument can be null if either of the integral arguments are zero and if both are non-zero, the pointer argument must not be null.

```
extern void *
my_memcpy (void *dest, const void *src, size_t len)
        __attribute__((nonnull (1, 2)));
extern void *
my_memcpy2 (void *dest, const void *src, size_t len)
        __attribute__((nonnull_if_nonzero (1, 3),
                       nonnull_if_nonzero (2, 3)));
extern size_t
my_fread (void *buf, size_t size, size_t count, FILE *stream)
        __attribute__((nonnull (4),
                       nonnull_if_nonzero (1, 2, 3)));
```

With these declarations, it is invalid to call `my_memcpy (NULL, NULL, 0);` or to call `my_memcpy2 (NULL, NULL, 4);` or to call `my_fread(`*buf*`, 0, 0, NULL);` or to call `my_fread(NULL, 1, 1, `*stream*`);` but it is valid to call `my_memcpy2 (NULL, NULL, 0);` or `my_fread(NULL, 0, 0, `*stream*`);` or `my_fread(NULL, 0, 1, `*stream*`);` or `my_fread(NULL, 1, 0, `*stream*`);`. This attribute should be used on declarations which have e.g. an exception for zero sizes, in which case null may be passed.

`noplt` The `noplt` attribute is the counterpart to option `-fno-plt`. Calls to functions marked with this attribute in position-independent code do not use the PLT.

```
/* Externally defined function foo.  */
int foo () __attribute__ ((noplt));

int
main (/* ... */)
{
  /* ... */
  foo ();
  /* ... */
}
```

The `noplt` attribute on function `foo` tells the compiler to assume that the function `foo` is externally defined and that the call to `foo` must avoid the PLT in position-independent code.

In position-dependent code, a few targets also convert calls to functions that are marked to not use the PLT to use the GOT instead.

`noreturn` A few standard library functions, such as `abort` and `exit`, cannot return. GCC knows this automatically. Some programs define their own functions that never return. You can declare them `noreturn` to tell the compiler this fact. For example,

```
void fatal () __attribute__ ((noreturn));

void
fatal (/* ... */)
{
  /* ... */ /* Print error message. */ /* ... */
  exit (1);
}
```

The `noreturn` keyword tells the compiler to assume that `fatal` cannot return. It can then optimize without regard to what would happen if `fatal` ever did return. This makes slightly better code. More importantly, it helps avoid spurious warnings of uninitialized variables.

The `noreturn` keyword does not affect the exceptional path when that applies: a `noreturn`-marked function may still return to the caller by throwing an exception or calling `longjmp`.

In order to preserve backtraces, GCC will never turn calls to `noreturn` functions into tail calls.

Do not assume that registers saved by the calling function are restored before calling the `noreturn` function.

It does not make sense for a `noreturn` function to have a return type other than `void`.

`nothrow` The `nothrow` attribute is used to inform the compiler that a function cannot throw an exception. For example, most functions in the standard C library can be guaranteed not to throw an exception with the notable exceptions of `qsort` and `bsearch` that take function pointer arguments.

`null_terminated_string_arg`
`null_terminated_string_arg (`*N*`)`

The `null_terminated_string_arg` attribute may be applied to a function that takes a `char *` or `const char *` at referenced argument *N*.

It indicates that the passed argument must be a C-style null-terminated string. Specifically, the presence of the attribute implies that, if the pointer is non-null, the function may scan through the referenced buffer looking for the first zero byte.

In particular, when the analyzer is enabled (via `-fanalyzer`), if the pointer is non-null, it will simulate scanning for the first zero byte in the referenced buffer, and potentially emit `-Wanalyzer-use-of-uninitialized-value` or `-Wanalyzer-out-of-bounds` on improperly terminated buffers.

For example, given the following:

```
char *example_1 (const char *p)
  __attribute__((null_terminated_string_arg (1)));
```

the analyzer will check that any non-null pointers passed to the function are validly terminated.

If the parameter must be non-null, it is appropriate to use both this attribute and the attribute `nonnull`, such as in:

```
extern char *example_2 (const char *p)
  __attribute__((null_terminated_string_arg (1),
                 nonnull (1)));
```

See the `nonnull` attribute for more information and caveats.

If the pointer argument is also referred to by an `access` attribute on the function with *access-mode* either `read_only` or `read_write` and the latter attribute has the optional *size-index* argument referring to a size argument, this expresses the maximum size of the access. For example, given:

```
extern char *example_fn (const char *p, size_t n)
```

```
__attribute__((null_terminated_string_arg (1),
               access (read_only, 1, 2),
               nonnull (1)));
```

the analyzer will require the first parameter to be non-null, and either be validly null-terminated, or validly readable up to the size specified by the second parameter.

`optimize (`*`level`*`, ...)`
`optimize (`*`string`*`, ...)`

The `optimize` attribute is used to specify that a function is to be compiled with different optimization options than specified on the command line. The optimize attribute arguments of a function behave as if appended to the command-line.

Valid arguments are constant non-negative integers and strings. Each numeric argument specifies an optimization *level*. Each *string* argument consists of one or more comma-separated substrings. Each substring that begins with the letter `O` refers to an optimization option such as `-O0` or `-Os`. Other substrings are taken as suffixes to the `-f` prefix jointly forming the name of an optimization option. See Section 3.12 [Optimize Options], page 194.

'`#pragma GCC optimize`' can be used to set optimization options for more than one function. See Section 6.5.16 [Function Specific Option Pragmas], page 745, for details about the pragma.

Providing multiple strings as arguments separated by commas to specify multiple options is equivalent to separating the option suffixes with a comma ('`,`') within a single string. Spaces are not permitted within the strings.

Not every optimization option that starts with the *-f* prefix specified by the attribute necessarily has an effect on the function. The `optimize` attribute should be used for debugging purposes only. It is not suitable in production code.

`patchable_function_entry`

In case the target's text segment can be made writable at run time by any means, padding the function entry with a number of NOPs can be used to provide a universal tool for instrumentation.

The `patchable_function_entry` function attribute can be used to change the number of NOPs to any desired value. The two-value syntax is the same as for the command-line switch `-fpatchable-function-entry=N,M`, generating N NOPs, with the function entry point before the Mth NOP instruction. M defaults to 0 if omitted e.g. function entry point is before the first NOP.

If patchable function entries are enabled globally using the command-line option `-fpatchable-function-entry=N,M`, then you must disable instrumentation on all functions that are part of the instrumentation framework with the attribute `patchable_function_entry (0)` to prevent recursion.

`pure`

Calls to functions that have no observable effects on the state of the program other than to return a value may lend themselves to optimizations such as common subexpression elimination. Declaring such functions with the `pure` attribute allows GCC to avoid emitting some calls in repeated invocations of the function with the same argument values.

The `pure` attribute prohibits a function from modifying the state of the program that is observable by means other than inspecting the function's return value. However, functions declared with the `pure` attribute can safely read any non-volatile objects, and modify the value of objects in a way that does not affect their return value or the observable state of the program.

For example,

```
int hash (char *) __attribute__ ((pure));
```

tells GCC that subsequent calls to the function `hash` with the same string can be replaced by the result of the first call provided the state of the program observable by `hash`, including the contents of the array itself, does not change in between. Even though `hash` takes a non-const pointer argument it must not modify the array it points to, or any other object whose value the rest of the program may depend on. However, the caller may safely change the contents of the array between successive calls to the function (doing so disables the optimization). The restriction also applies to member objects referenced by the `this` pointer in C++ non-static member functions.

Some common examples of pure functions are `strlen` or `memcmp`. Interesting non-pure functions are functions with infinite loops or those depending on volatile memory or other system resource, that may change between consecutive calls (such as the standard C `feof` function in a multithreading environment).

The `pure` attribute imposes similar but looser restrictions on a function's definition than the `const` attribute: `pure` allows the function to read any non-volatile memory, even if it changes in between successive invocations of the function. Declaring the same function with both the `pure` and the `const` attribute is diagnosed. Because a pure function cannot have any observable side effects it does not make sense for such a function to return `void`. Declaring such a function is diagnosed.

`unsequenced`

This attribute is a GNU counterpart of the C23 `[[unsequenced]]` attribute, used to specify function pointers to effectless, idempotent, stateless and independent functions according to the C23 definition.

Unlike the standard C23 attribute it can be also specified in attributes which appertain to function declarations and applies to the their function type even in that case.

Unsequenced functions without pointer or reference arguments are similar to functions with the `const` attribute, except that `const` attribute also requires finiteness. So, both functions with `const` and with `unsequenced` attributes can be optimized by common subexpression elimination, but only functions with `const` attribute can be optimized by dead code elimination if their result is unused or is used only by dead code. Unsequenced functions without pointer or reference arguments with `void` return type are diagnosed because they can't store any results and don't have other observable side-effects either.

Unsequenced functions with pointer or reference arguments can inspect objects through the passed pointers or references or references to pointers or can store additional results through those pointers or references or references to pointers.

The `unsequenced` attribute imposes greater restrictions than the similar `reproducible` attribute and fewer restrictions than the `const` attribute, so during optimization `const` has precedence over `unsequenced` which has precedence over `reproducible`.

`reproducible`

This attribute is a GNU counterpart of the C23 `[[reproducible]]` attribute, used to specify function pointers to effectless and idempotent functions according to the C23 definition.

Unlike the standard C23 attribute it can be also specified in attributes which appertain to function declarations and applies to the their function type even in that case.

Reproducible functions without pointer or reference arguments or which do not modify objects referenced by those pointer/reference arguments are similar to functions with the `pure` attribute, except that `pure` attribute also requires finiteness. So, both functions with `pure` and with `reproducible` attributes can be optimized by common subexpression elimination if the global state or anything reachable through the pointer/reference arguments isn't modified, but only functions with `pure` attribute can be optimized by dead code elimination if their result is unused or is used only by dead code. Reproducible functions without pointer or reference arguments with `void` return type are diagnosed because they can't store any results and don't have other observable side-effects either.

Reproducible functions with pointer or reference arguments can store additional results through those pointers or references or references to pointers.

`retain` For ELF targets that support the GNU or FreeBSD OSABIs, this attribute will save the function from linker garbage collection. To support this behavior, functions that have not been placed in specific sections (e.g. by the `section` attribute, or the `-ffunction-sections` option), will be placed in new, unique sections.

This additional functionality requires Binutils version 2.36 or later.

`returns_nonnull`

The `returns_nonnull` attribute specifies that the function return value should be a non-null pointer. For instance, the declaration:

```
extern void *
mymalloc (size_t len) __attribute__((returns_nonnull));
```

lets the compiler optimize callers based on the knowledge that the return value will never be null.

`returns_twice`

The `returns_twice` attribute tells the compiler that a function may return more than one time. The compiler ensures that all registers are dead before calling such a function and emits a warning about the variables that may be clobbered after the second return from the function. Examples of such functions are `setjmp` and `vfork`. The `longjmp`-like counterpart of such function, if any, might need to be marked with the `noreturn` attribute.

`section ("`*`section-name`*`")`

Normally, the compiler places the code it generates in the `text` section. Sometimes, however, you need additional sections, or you need certain particular functions to appear in special sections. The `section` attribute specifies that a function lives in a particular section. For example, the declaration:

```
extern void foobar (void) __attribute__ ((section ("bar")));
```

puts the function `foobar` in the `bar` section.

Some file formats do not support arbitrary sections so the `section` attribute is not available on all platforms. If you need to map the entire contents of a module to a particular section, consider using the facilities of the linker instead.

`sentinel`
`sentinel (`*`position`*`)`

This function attribute indicates that an argument in a call to the function is expected to be an explicit `NULL`. The attribute is only valid on variadic functions. By default, the sentinel is expected to be the last argument of the function call. If the optional *position* argument is specified to the attribute, the sentinel must be located at *position* counting backwards from the end of the argument list.

```
__attribute__ ((sentinel))
is equivalent to
__attribute__ ((sentinel(0)))
```

The attribute is automatically set with a position of 0 for the built-in functions `execl` and `execlp`. The built-in function `execle` has the attribute set with a position of 1.

A valid `NULL` in this context is defined as zero with any object pointer type. If your system defines the `NULL` macro with an integer type then you need to add an explicit cast. During installation GCC replaces the system <stddef.h> header with a copy that redefines NULL appropriately.

The warnings for missing or incorrect sentinels are enabled with `-Wformat`.

`simd`
`simd("`*`mask`*`")`

This attribute enables creation of one or more function versions that can process multiple arguments using SIMD instructions from a single invocation. Specifying this attribute allows compiler to assume that such versions are available at link time (provided in the same or another translation unit). Generated versions are target-dependent and described in the corresponding Vector ABI document. For x86_64 target this document can be found here (`https://sourceware.org/glibc/wiki/libmvec?action=AttachFile&do=view&target=VectorABI.txt`).

The optional argument *mask* may have the value `notinbranch` or `inbranch`, and instructs the compiler to generate non-masked or masked clones correspondingly. By default, all clones are generated.

If the attribute is specified and `#pragma omp declare simd` is present on a declaration and the `-fopenmp` or `-fopenmp-simd` switch is specified, then the attribute is ignored.

`stack_protect`
: This attribute adds stack protection code to the function if flags `-fstack-protector`, `-fstack-protector-strong` or `-fstack-protector-explicit` are set.

`symver ("name2@nodename")`
: On ELF targets this attribute creates a symbol version. The *name2* part of the parameter is the actual name of the symbol by which it will be externally referenced. The `nodename` portion should be the name of a node specified in the version script supplied to the linker when building a shared library. Versioned symbol must be defined and must be exported with default visibility.

```
__attribute__ ((__symver__ ("foo@VERS_1"))) int
foo_v1 (void)
{
}
```

Will produce a `.symver foo_v1, foo@VERS_1` directive in the assembler output.

One can also define multiple version for a given symbol (starting from binutils 2.35).

```
__attribute__ ((__symver__ ("foo@VERS_2"), __symver__ ("foo@VERS_3")))
int symver_foo_v1 (void)
{
}
```

This example creates a symbol name `symver_foo_v1` which will be version `VERS_2` and `VERS_3` of `foo`.

If you have an older release of binutils, then symbol alias needs to be used:

```
__attribute__ ((__symver__ ("foo@VERS_2")))
int foo_v1 (void)
{
  return 0;
}

__attribute__ ((__symver__ ("foo@VERS_3")))
__attribute__ ((alias ("foo_v1")))
int symver_foo_v1 (void);
```

Finally if the parameter is `"name2@@nodename"` then in addition to creating a symbol version (as if `"name2@nodename"` was used) the version will be also used to resolve *name2* by the linker.

`tainted_args`
: The `tainted_args` attribute is used to specify that a function is called in a way that requires sanitization of its arguments, such as a system call in an operating system kernel. Such a function can be considered part of the "attack surface" of the program. The attribute can be used both on function declarations, and on field declarations containing function pointers. In the latter case, any function used as an initializer of such a callback field will be treated as being called with tainted arguments.

The analyzer will pay particular attention to such functions when `-fanalyzer` is supplied, potentially issuing warnings guarded by `-Wanalyzer-tainted-allocation-size`, `-Wanalyzer-tainted-array-index`, `-Wanalyzer-tainted-divisor`, `-Wanalyzer-tainted-offset`, and `-Wanalyzer-tainted-size`.

`target (`*string*`, ...)`

Multiple target back ends implement the `target` attribute to specify that a function is to be compiled with different target options than specified on the command line. The original target command-line options are ignored. One or more strings can be provided as arguments. Each string consists of one or more comma-separated suffixes to the `-m` prefix jointly forming the name of a machine-dependent option. See Section 3.20 [Machine-Dependent Options], page 345.

The `target` attribute can be used for instance to have a function compiled with a different ISA (instruction set architecture) than the default. '`#pragma GCC target`' can be used to specify target-specific options for more than one function. See Section 6.5.16 [Function Specific Option Pragmas], page 745, for details about the pragma.

For instance, on an x86, you could declare one function with the `target("sse4.1,arch=core2")` attribute and another with `target("sse4a,arch=amdfam10")`. This is equivalent to compiling the first function with `-msse4.1` and `-march=core2` options, and the second function with `-msse4a` and `-march=amdfam10` options. It is up to you to make sure that a function is only invoked on a machine that supports the particular ISA it is compiled for (for example by using `cpuid` on x86 to determine what feature bits and architecture family are used).

```
int core2_func (void) __attribute__ ((__target__ ("arch=core2")));
int sse3_func (void) __attribute__ ((__target__ ("sse3")));
```

Providing multiple strings as arguments separated by commas to specify multiple options is equivalent to separating the option suffixes with a comma ('`,`') within a single string. Spaces are not permitted within the strings.

The options supported are specific to each target; refer to Section 6.4.1.33 [x86 Function Attributes], page 685, Section 6.4.1.24 [PowerPC Function Attributes], page 677, Section 6.4.1.5 [ARM Function Attributes], page 657, Section 6.4.1.2 [AArch64 Function Attributes], page 652, and Section 6.4.1.28 [S/390 Function Attributes], page 683, for details.

On targets supporting `target` function multiversioning (x86), when using C++, you can declare multiple functions with the same signatures but different `target` attribute values, and the correct version is chosen by the dynamic linker. In the example below, two function versions are produced with differing mangling. Additionally an ifunc resolver is created to select the correct version to populate the `func` symbol.

```
int func (void) __attribute__ ((target ("arch=core2"))) { return 1; }
int func (void) __attribute__ ((target ("sse3"))) { return 2; }
```

Declarations annotated with `target` cannot be used in combination with declarations annotated with `target_clones` in a single multiversioned function definition.

See Section 8.8 [Function Multiversioning], page 1069, for more details.

`target_version (`*`option`*`)`

On targets with `target_version` function multiversioning (AArch64 and RISC-V) in C or C++, you can declare multiple functions with `target_version` or `target_clones` attributes to define a function version set.

See Section 8.8 [Function Multiversioning], page 1069, for more details.

`target_clones (`*`options`*`)`

The `target_clones` attribute is used to specify that a function be cloned into multiple versions compiled with different target options than specified on the command line.

For the x86 and PowerPC targets, the supported options and restrictions are the same as for the `target` attribute.

For instance, on an x86, you could compile a function with `target_clones("sse4.1,avx")`. GCC creates two function clones, one compiled with `-msse4.1` and another with `-mavx`.

On a PowerPC, you can compile a function with `target_clones("cpu=power9,default")`. GCC will create two function clones, one compiled with `-mcpu=power9` and another with the default options. GCC must be configured to use GLIBC 2.23 or newer in order to use the `target_clones` attribute.

`target_clones` works similarly for targets that support the `target_version` attribute (AArch64 and RISC-V). The attribute takes multiple arguments, and generates a versioned clone for each. A function annotated with `target_clones` is equivalent to the same function duplicated for each valid version string in the argument, where each version is instead annotated with `target_version`. This means that a `target_clones` annotated function definition can be used in combination with `target_version` annotated functions definitions and other `target_clones` annotated function definitions.

For these targets the supported options and restrictions are the same as for the `target_version` attribute.

See Section 8.8 [Function Multiversioning], page 1069, for more details.

`unavailable`
`unavailable (`*`msg`*`)`

The `unavailable` attribute results in an error if the function is used anywhere in the source file. This is useful when identifying functions that have been removed from a particular variation of an interface. Other than emitting an error rather than a warning, the `unavailable` attribute behaves in the same manner as `deprecated`.

The `unavailable` attribute can also be used for variables and types (see Section 6.4.2 [Variable Attributes], page 699, see Section 6.4.3 [Type Attributes], page 715.)

`unused` This attribute, attached to a function, means that the function is meant to be possibly unused. GCC does not produce a warning for this function.

`used` This attribute, attached to a function, means that code must be emitted for the function even if it appears that the function is not referenced. This is useful, for example, when the function is referenced only in inline assembly.

When applied to a member function of a C++ class template, the attribute also means that the function is instantiated if the class itself is instantiated.

`visibility ("`*`visibility_type`*`")`

This attribute affects the linkage of the declaration to which it is attached. It can be applied to variables (see Section 6.4.2.1 [Common Variable Attributes], page 699) and types (see Section 6.4.3.1 [Common Type Attributes], page 715) as well as functions.

There are four supported *visibility_type* values: default, hidden, protected or internal visibility.

```
void __attribute__ ((visibility ("protected")))
f () { /* Do something. */; }
int i __attribute__ ((visibility ("hidden")));
```

The possible values of *visibility_type* correspond to the visibility settings in the ELF gABI.

`default` Default visibility is the normal case for the object file format. This value is available for the visibility attribute to override other options that may change the assumed visibility of entities.

On ELF, default visibility means that the declaration is visible to other modules and, in shared libraries, means that the declared entity may be overridden.

On Darwin, default visibility means that the declaration is visible to other modules.

Default visibility corresponds to "external linkage" in the language.

`hidden` Hidden visibility indicates that the entity declared has a new form of linkage, which we call "hidden linkage". Two declarations of an object with hidden linkage refer to the same object if they are in the same shared object.

`internal` Internal visibility is like hidden visibility, but with additional processor specific semantics. Unless otherwise specified by the psABI, GCC defines internal visibility to mean that a function is *never* called from another module. Compare this with hidden functions which, while they cannot be referenced directly by other modules, can be referenced indirectly via function pointers. By indicating that a function cannot be called from outside the module, GCC may for instance omit the load of a PIC register since it is known that the calling function loaded the correct value.

`protected`

Protected visibility is like default visibility except that it indicates that references within the defining module bind to the definition in that module. That is, the declared entity cannot be overridden by another module.

All visibilities are supported on many, but not all, ELF targets (supported when the assembler supports the '.visibility' pseudo-op). Default visibility is supported everywhere. Hidden visibility is supported on Darwin targets.

The visibility attribute should be applied only to declarations that would otherwise have external linkage. The attribute should be applied consistently, so that the same entity should not be declared with different settings of the attribute.

In C++, the visibility attribute applies to types as well as functions and objects, because in C++ types have linkage. A class must not have greater visibility than its non-static data member types and bases, and class members default to the visibility of their class. Also, a declaration without explicit visibility is limited to the visibility of its type.

In C++, you can mark member functions and static member variables of a class with the visibility attribute. This is useful if you know a particular method or static member variable should only be used from one shared object; then you can mark it hidden while the rest of the class has default visibility. Care must be taken to avoid breaking the One Definition Rule; for example, it is usually not useful to mark an inline method as hidden without marking the whole class as hidden.

A C++ namespace declaration can also have the visibility attribute.

```
namespace nspace1 __attribute__ ((visibility ("protected")))
{ /* Do something. */; }
```

This attribute applies only to the particular namespace body, not to other definitions of the same namespace; it is equivalent to using '#pragma GCC visibility' before and after the namespace definition (see Section 6.5.14 [Visibility Pragmas], page 744).

In C++, if a template argument has limited visibility, this restriction is implicitly propagated to the template instantiation. Otherwise, template instantiations and specializations default to the visibility of their template.

If both the template and enclosing class have explicit visibility, the visibility from the template is used.

`warn_unused_result`

The `warn_unused_result` attribute causes a warning to be emitted if a caller of the function with this attribute does not use its return value. This is useful for functions where not checking the result is either a security problem or always a bug, such as `realloc`.

```
int fn () __attribute__ ((warn_unused_result));
int foo ()
{
  if (fn () < 0) return -1;
  fn ();
  return 0;
}
```

results in warning on line 5.

`weak` The `weak` attribute causes a declaration of an external symbol to be emitted as a weak symbol rather than a global. This is primarily useful in defining library functions that can be overridden in user code, though it can also be used with non-function declarations. The overriding symbol must have the same type as the weak symbol. In addition, if it designates a variable it must also have the same size and alignment as the weak symbol. Weak symbols are supported for ELF targets, and also for a.out targets when using the GNU assembler and linker.

`weakref`
`weakref ("`*`target`*`")`

The `weakref` attribute marks a declaration as a weak reference. Without arguments, it should be accompanied by an `alias` attribute naming the target symbol. Alternatively, *target* may be given as an argument to `weakref` itself, naming the target definition of the alias. The *target* must have the same type as the declaration. In addition, if it designates a variable it must also have the same size and alignment as the declaration. In either form of the declaration `weakref` implicitly marks the declared symbol as `weak`. Without a *target* given as an argument to `weakref` or to `alias`, `weakref` is equivalent to `weak` (in that case the declaration may be `extern`).

```
/* Given the declaration: */
extern int y (void);

/* the following... */
static int x (void) __attribute__ ((weakref ("y")));

/* is equivalent to... */
static int x (void) __attribute__ ((weakref, alias ("y")));

/* or, alternatively, to... */
static int x (void) __attribute__ ((weakref));
static int x (void) __attribute__ ((alias ("y")));
```

A weak reference is an alias that does not by itself require a definition to be given for the target symbol. If the target symbol is only referenced through weak references, then it becomes a `weak` undefined symbol. If it is directly referenced, however, then such strong references prevail, and a definition is required for the symbol, not necessarily in the same translation unit.

The effect is equivalent to moving all references to the alias to a separate translation unit, renaming the alias to the aliased symbol, declaring it as weak, compiling the two separate translation units and performing a link with relocatable output (i.e. `ld -r`) on them.

A declaration to which `weakref` is attached and that is associated with a named `target` must be `static`.

`zero_call_used_regs ("`*`choice`*`")`

The `zero_call_used_regs` attribute causes the compiler to zero a subset of all call-used registers[1] at function return. This is used to increase program

[1] A "call-used" register is a register whose contents can be changed by a function call; therefore, a caller cannot assume that the register has the same contents on return from the function as it had before calling the function. Such registers are also called "call-clobbered", "caller-saved", or "volatile".

security by either mitigating Return-Oriented Programming (ROP) attacks or preventing information leakage through registers.

In order to satisfy users with different security needs and control the run-time overhead at the same time, the *choice* parameter provides a flexible way to choose the subset of the call-used registers to be zeroed. The four basic values of *choice* are:

- '`skip`' doesn't zero any call-used registers.
- '`used`' only zeros call-used registers that are used in the function. A "used" register is one whose content has been set or referenced in the function.
- '`all`' zeros all call-used registers.
- '`leafy`' behaves like '`used`' in a leaf function, and like '`all`' in a nonleaf function. This makes for leaner zeroing in leaf functions, where the set of used registers is known, and that may be enough for some purposes of register zeroing.

In addition to these three basic choices, it is possible to modify '`used`', '`all`', and '`leafy`' as follows:

- Adding '`-gpr`' restricts the zeroing to general-purpose registers.
- Adding '`-arg`' restricts the zeroing to registers that can sometimes be used to pass function arguments. This includes all argument registers defined by the platform's calling conversion, regardless of whether the function uses those registers for function arguments or not.

The modifiers can be used individually or together. If they are used together, they must appear in the order above.

The full list of *choice*s is therefore:

`skip` doesn't zero any call-used register.

`used` only zeros call-used registers that are used in the function.

`used-gpr` only zeros call-used general purpose registers that are used in the function.

`used-arg` only zeros call-used registers that are used in the function and pass arguments.

`used-gpr-arg`
: only zeros call-used general purpose registers that are used in the function and pass arguments.

`all` zeros all call-used registers.

`all-gpr` zeros all call-used general purpose registers.

`all-arg` zeros all call-used registers that pass arguments.

`all-gpr-arg`
: zeros all call-used general purpose registers that pass arguments.

`leafy` Same as '`used`' in a leaf function, and same as '`all`' in a nonleaf function.

`leafy-gpr`
: Same as '`used-gpr`' in a leaf function, and same as '`all-gpr`' in a nonleaf function.

`leafy-arg`
: Same as '`used-arg`' in a leaf function, and same as '`all-arg`' in a nonleaf function.

`leafy-gpr-arg`
: Same as '`used-gpr-arg`' in a leaf function, and same as '`all-gpr-arg`' in a nonleaf function.

Of this list, '`used-arg`', '`used-gpr-arg`', '`all-arg`', '`all-gpr-arg`', '`leafy-arg`', and '`leafy-gpr-arg`' are mainly used for ROP mitigation.

The default for the attribute is controlled by `-fzero-call-used-regs`.

6.4.1.2 AArch64 Function Attributes

The following target-specific function attributes are available for the AArch64 target. For the most part, these options mirror the behavior of similar command-line options (see Section 3.20.1 [AArch64 Options], page 345), but on a per-function basis.

`general-regs-only`
: Indicates that no floating-point or Advanced SIMD registers should be used when generating code for this function. If the function explicitly uses floating-point code, then the compiler gives an error. This is the same behavior as that of the command-line option `-mgeneral-regs-only`.

`fix-cortex-a53-835769`
: Indicates that the workaround for the Cortex-A53 erratum 835769 should be applied to this function. To explicitly disable the workaround for this function specify the negated form: `no-fix-cortex-a53-835769`. This corresponds to the behavior of the command-line options `-mfix-cortex-a53-835769` and `-mno-fix-cortex-a53-835769`.

`cmodel=`
: Indicates that code should be generated for a particular code model for this function. The behavior and permissible arguments are the same as for the command-line option `-mcmodel=`.

`strict-align`
`no-strict-align`
: `strict-align` indicates that the compiler should not assume that unaligned memory references are handled by the system. To allow the compiler to assume that aligned memory references are handled by the system, the inverse attribute `no-strict-align` can be specified. The behavior is same as for the command-line option `-mstrict-align` and `-mno-strict-align`.

`omit-leaf-frame-pointer`
: Indicates that the frame pointer should be omitted for a leaf function call. To keep the frame pointer, the inverse attribute `no-omit-leaf-frame-pointer` can be specified. These attributes have the same behavior as the command-line options `-momit-leaf-frame-pointer` and `-mno-omit-leaf-frame-pointer`.

`tls-dialect=`
: Specifies the TLS dialect to use for this function. The behavior and permissible arguments are the same as for the command-line option `-mtls-dialect=`.

`arch=`
: Specifies the architecture version and architectural extensions to use for this function. The behavior and permissible arguments are the same as for the `-march=` command-line option.

`tune=`
: Specifies the core for which to tune the performance of this function. The behavior and permissible arguments are the same as for the `-mtune=` command-line option.

`cpu=`
: Specifies the core for which to tune the performance of this function and also whose architectural features to use. The behavior and valid arguments are the same as for the `-mcpu=` command-line option.

`sign-return-address`
: Select the function scope on which return address signing will be applied. The behavior and permissible arguments are the same as for the command-line option `-msign-return-address=`. The default value is `none`. This attribute is deprecated. The `branch-protection` attribute should be used instead.

`branch-protection`
: Select the function scope on which branch protection will be applied. The behavior and permissible arguments are the same as for the command-line option `-mbranch-protection=`. The default value is `none`.

`outline-atomics`
`no-outline-atomics`
: Enable or disable calls to out-of-line helpers to implement atomic operations. This corresponds to the behavior of the command-line options `-moutline-atomics` and `-mno-outline-atomics`.

`max-vectorization`
`no-max-vectorization`
: `max-vectorization` tells GCC's vectorizer to treat all vector loops as being more profitable than the original scalar loops when optimizing the current function. `no-max-vectorization` disables this behavior. This corresponds to the behavior of the command-line options `-mmax-vectorization` and `-mno-max-vectorization`.

`indirect_return`
: The `indirect_return` attribute can be applied to a function type to indicate that the function may return via an indirect branch instead of via a normal return instruction. For example, this can be true of functions that implement manual context switching between user space threads, such as the POSIX `swapcontext` function. This attribute adds a `BTI J` instruction when BTI is enabled e.g. via `-mbranch-protection`.

`preserve_none`
: Use this attribute to change the procedure call standard of the specified function to the preserve-none variant.

The preserve-none ABI variant modifies the AAPCS such that it has no callee-saved registers (including SIMD and floating-point registers). That is, with the exception of the stack register, link register (r30), and frame pointer (r29), all registers are changed to caller saved, and can be used as scratch registers by the callee.

Additionally, registers r20–r28, r0–r7, r10–r14, r9 and r15 are used for argument passing, in that order. For Microsoft Windows targets r15 is not used for argument passing.

The return value registers remain r0 and r1 in both cases.

All other details are the same as for the AAPCS ABI.

This ABI has not been stabilized, and may be subject to change in future versions.

The above target attributes can be specified as follows:

```
__attribute__((target("attr-string")))
int
f (int a)
{
  return a + 5;
}
```

where *attr-string* is one of the attribute strings specified above.

Additionally, the architectural extension string may be specified on its own. This can be used to turn on and off particular architectural extensions without having to specify a particular architecture version or core. Example:

```
__attribute__((target("+crc+nocrypto")))
int
foo (int a)
{
  return a + 5;
}
```

In this example `target("+crc+nocrypto")` enables the `crc` extension and disables the `crypto` extension for the function `foo` without modifying an existing `-march=` or `-mcpu` option.

Multiple target function attributes can be specified by separating them with a comma. For example:

```
__attribute__((target("arch=armv8-a+crc+crypto,tune=cortex-a53")))
int
foo (int a)
{
  return a + 5;
}
```

is valid and compiles function `foo` for ARMv8-A with `crc` and `crypto` extensions and tunes it for `cortex-a53`.

Inlining rules

Specifying target attributes on individual functions or performing link-time optimization across translation units compiled with different target options can affect function inlining rules:

In particular, a caller function can inline a callee function only if the architectural features available to the callee are a subset of the features available to the caller. For example: A function `foo` compiled with `-march=armv8-a+crc`, or tagged with the equivalent `arch=armv8-a+crc` attribute, can inline a function `bar` compiled with `-march=armv8-a+nocrc` because the all the architectural features that function `bar` requires are available to function `foo`. Conversely, function `bar` cannot inline function `foo`.

Additionally inlining a function compiled with `-mstrict-align` into a function compiled without `-mstrict-align` is not allowed. However, inlining a function compiled without `-mstrict-align` into a function compiled with `-mstrict-align` is allowed.

Note that CPU tuning options and attributes such as the `-mcpu=`, `-mtune=` do not inhibit inlining unless the CPU specified by the `-mcpu=` option or the `cpu=` attribute conflicts with the architectural feature rules specified above.

6.4.1.3 AMD GCN Function Attributes

These function attributes are supported by the AMD GCN back end:

`amdgpu_hsa_kernel`

This attribute indicates that the corresponding function should be compiled as a kernel function, that is an entry point that can be invoked from the host via the HSA runtime library. By default functions are only callable only from other GCN functions.

This attribute is implicitly applied to any function named `main`, using default parameters.

Kernel functions may return an integer value, which will be written to a conventional place within the HSA "kernargs" region.

The attribute parameters configure what values are passed into the kernel function by the GPU drivers, via the initial register state. Some values are used by the compiler, and therefore forced on. Enabling other options may break assumptions in the compiler and/or run-time libraries.

`private_segment_buffer`

Set `enable_sgpr_private_segment_buffer` flag. Always on (required to locate the stack).

`dispatch_ptr`

Set `enable_sgpr_dispatch_ptr` flag. Always on (required to locate the launch dimensions).

`queue_ptr`

Set `enable_sgpr_queue_ptr` flag. Always on (required to convert address spaces).

`kernarg_segment_ptr`

Set `enable_sgpr_kernarg_segment_ptr` flag. Always on (required to locate the kernel arguments, "kernargs").

`dispatch_id`

Set `enable_sgpr_dispatch_id` flag.

`flat_scratch_init`
: Set `enable_sgpr_flat_scratch_init` flag.

`private_segment_size`
: Set `enable_sgpr_private_segment_size` flag.

`grid_workgroup_count_X`
: Set `enable_sgpr_grid_workgroup_count_x` flag. Always on (required to use OpenACC/OpenMP).

`grid_workgroup_count_Y`
: Set `enable_sgpr_grid_workgroup_count_y` flag.

`grid_workgroup_count_Z`
: Set `enable_sgpr_grid_workgroup_count_z` flag.

`workgroup_id_X`
: Set `enable_sgpr_workgroup_id_x` flag.

`workgroup_id_Y`
: Set `enable_sgpr_workgroup_id_y` flag.

`workgroup_id_Z`
: Set `enable_sgpr_workgroup_id_z` flag.

`workgroup_info`
: Set `enable_sgpr_workgroup_info` flag.

`private_segment_wave_offset`
: Set `enable_sgpr_private_segment_wave_byte_offset` flag. Always on (required to locate the stack).

`work_item_id_X`
: Set `enable_vgpr_workitem_id` parameter. Always on (can't be disabled).

`work_item_id_Y`
: Set `enable_vgpr_workitem_id` parameter. Always on (required to enable vectorization.)

`work_item_id_Z`
: Set `enable_vgpr_workitem_id` parameter. Always on (required to use OpenACC/OpenMP).

6.4.1.4 ARC Function Attributes

These function attributes are supported by the ARC back end:

`interrupt`
: Use this attribute to indicate that the specified function is an interrupt handler. The compiler generates function entry and exit sequences suitable for use in an interrupt handler when this attribute is present.

  On the ARC, you must specify the kind of interrupt to be handled in a parameter to the interrupt attribute like this:

```
void f () __attribute__ ((interrupt ("ilink1")));
```

Permissible values for this parameter are: `ilink1` and `ilink2` for ARCv1 architecture, and `ilink` and `firq` for ARCv2 architecture.

`long_call`
`medium_call`
`short_call`
These attributes specify how a particular function is called. These attributes override the `-mlong-calls` and `-mmedium-calls` (see Section 3.20.4 [ARC Options], page 361) command-line switches and `#pragma long_calls` settings.

For ARC, a function marked with the `long_call` attribute is always called using register-indirect jump-and-link instructions, thereby enabling the called function to be placed anywhere within the 32-bit address space. A function marked with the `medium_call` attribute will always be close enough to be called with an unconditional branch-and-link instruction, which has a 25-bit offset from the call site. A function marked with the `short_call` attribute will always be close enough to be called with a conditional branch-and-link instruction, which has a 21-bit offset from the call site.

`jli_always`
Forces a particular function to be called using `jli` instruction. The `jli` instruction makes use of a table stored into `.jlitab` section, which holds the location of the functions which are addressed using this instruction.

`jli_fixed`
Identical like the above one, but the location of the function in the `jli` table is known and given as an attribute parameter.

`secure_call`
This attribute allows one to mark secure-code functions that are callable from normal mode. The location of the secure call function into the `sjli` table needs to be passed as argument.

`naked` This attribute allows the compiler to construct the requisite function declaration, while allowing the body of the function to be assembly code. The specified function will not have prologue/epilogue sequences generated by the compiler. Only basic `asm` statements can safely be included in naked functions (see Section 6.11.1 [Basic Asm], page 753). While using extended `asm` or a mixture of basic `asm` and C code may appear to work, they cannot be depended upon to work reliably and are not supported.

6.4.1.5 ARM Function Attributes

These function attributes are supported for ARM targets:

`general-regs-only`
Indicates that no floating-point or Advanced SIMD registers should be used when generating code for this function. If the function explicitly uses floating-point code, then the compiler gives an error. This is the same behavior as that of the command-line option `-mgeneral-regs-only`.

`interrupt`
: Use this attribute to indicate that the specified function is an interrupt handler. The compiler generates function entry and exit sequences suitable for use in an interrupt handler when this attribute is present.

  You can specify the kind of interrupt to be handled by adding an optional parameter to the interrupt attribute like this:

```
void f () __attribute__ ((interrupt ("IRQ")));
```

  Permissible values for this parameter are: `IRQ`, `FIQ`, `SWI`, `ABORT` and `UNDEF`.

  On ARMv7-M the interrupt type is ignored, and the attribute means the function may be called with a word-aligned stack pointer.

`isr`
: Use this attribute on ARM to write Interrupt Service Routines. This is an alias to the `interrupt` attribute above.

`long_call`
`short_call`
: These attributes specify how a particular function is called. These attributes override the `-mlong-calls` (see Section 3.20.5 [ARM Options], page 371) command-line switch and `#pragma long_calls` settings. For ARM, the `long_call` attribute indicates that the function might be far away from the call site and require a different (more expensive) calling sequence. The `short_call` attribute always places the offset to the function from the call site into the 'BL' instruction directly.

`naked`
: This attribute allows the compiler to construct the requisite function declaration, while allowing the body of the function to be assembly code. The specified function will not have prologue/epilogue sequences generated by the compiler. Only basic `asm` statements can safely be included in naked functions (see Section 6.11.1 [Basic Asm], page 753). While using extended `asm` or a mixture of basic `asm` and C code may appear to work, they cannot be depended upon to work reliably and are not supported.

`pcs`
: The `pcs` attribute can be used to control the calling convention used for a function on ARM. The attribute takes an argument that specifies the calling convention to use.

  When compiling using the AAPCS ABI (or a variant of it) then valid values for the argument are `"aapcs"` and `"aapcs-vfp"`. In order to use a variant other than `"aapcs"` then the compiler must be permitted to use the appropriate co-processor registers (i.e., the VFP registers must be available in order to use `"aapcs-vfp"`). For example,

```
/* Argument passed in r0, and result returned in r0+r1.  */
double f2d (float) __attribute__((pcs("aapcs")));
```

  Variadic functions always use the `"aapcs"` calling convention and the compiler rejects attempts to specify an alternative.

`target (`*options*`)`
: As discussed in Section 6.4.1.1 [Common Function Attributes], page 622, this attribute allows specification of target-specific compilation options.

On ARM, the following options are allowed:

'thumb' Force code generation in the Thumb (T16/T32) ISA, depending on the architecture level.

'arm' Force code generation in the ARM (A32) ISA.

Functions from different modes can be inlined in the caller's mode.

'fpu=' Specifies the fpu for which to tune the performance of this function. The behavior and permissible arguments are the same as for the -mfpu= command-line option.

'arch=' Specifies the architecture version and architectural extensions to use for this function. The behavior and permissible arguments are the same as for the -march= command-line option.

The above target attributes can be specified as follows:

```
__attribute__((target("arch=armv8-a+crc")))
int
f (int a)
{
  return a + 5;
}
```

Additionally, the architectural extension string may be specified on its own. This can be used to turn on and off particular architectural extensions without having to specify a particular architecture version or core. Example:

```
__attribute__((target("+crc+nocrypto")))
int
foo (int a)
{
  return a + 5;
}
```

In this example `target("+crc+nocrypto")` enables the `crc` extension and disables the `crypto` extension for the function `foo` without modifying an existing `-march=` or `-mcpu` option.

6.4.1.6 AVR Function Attributes

These function attributes are supported by the AVR back end:

`signal`
`interrupt`

The function is an interrupt service routine (ISR). The compiler generates function entry and exit sequences suitable for use in an interrupt handler when one of the attributes is present.

The AVR hardware globally disables interrupts when an interrupt is executed.

- ISRs with the `signal` attribute do not re-enable interrupts. It is save to enable interrupts in a `signal` handler. This "save" only applies to the code generated by the compiler and not to the IRQ layout of the application which is responsibility of the application.
- ISRs with the `interrupt` attribute re-enable interrupts. The first instruction of the routine is a `SEI` instruction to globally enable interrupts.

The recommended way to use these attributes is by means of the ISR macro provided by avr/interrupt.h from AVR-LibC:

```
#include <avr/interrupt.h>

ISR (INT0_vect) // Uses the "signal" attribute.
{
    // Code
}

ISR (ADC_vect, ISR_NOBLOCK) // Uses the "interrupt" attribute.
{
    // Code
}
```

When both signal and interrupt are specified for the same function, then signal is silently ignored.

signal(*num*)
interrupt(*num*)

Similar to the signal resp. interrupt attribute without argument, but the IRQ number is supplied as an argument *num* to the attribute, rather than providing the ISR name itself as the function name:

```
__attribute__((signal(1)))
static void my_handler (void)
{
   // Code for __vector_1
}
```

Notice that the handler function needs not to be externally visible. The recommended way to use these attributes is by means of the ISR_N macro provided by avr/interrupt.h from AVR-LibC:

```
#include <avr/interrupt.h>

ISR_N (PCINT0_vect_num)
static void my_pcint0_handler (void)
{
   // Code
}

ISR_N (ADC_vect_num, ISR_NOBLOCK)
static void my_adc_handler (void)
{
    // Code
}
```

ISR_N can be specified more than once, in which case several interrupt vectors are pointing to the same handler function. This is similar to the ISR_ALIASOF macro provided by AVR-LibC, but without the overhead introduced by ISR_ALIASOF.

`noblock`
: This attribute can be used together with the `signal` attribute to indicate that an interrupt service routine should start with a `SEI` instruction to globally re-enable interrupts. Using attributes `signal` and `noblock` together has the same effect like using the `interrupt` attribute. Using the `noblock` attribute without `signal` has no effect.

`naked`
: This attribute allows the compiler to construct the requisite function declaration, while allowing the body of the function to be assembly code. The specified function will not have prologue/epilogue sequences generated by the compiler. Only basic `asm` statements can safely be included in naked functions (see Section 6.11.1 [Basic Asm], page 753). While using extended `asm` or a mixture of basic `asm` and C code may appear to work, they cannot be depended upon to work reliably and are not supported.

`no_gccisr`
: Do not use the `__gcc_isr` pseudo instruction (`https://sourceware.org/binutils/docs/as/AVR-Pseudo-Instructions.html`) in a function with the `interrupt` or `signal` attribute aka. interrupt service routine (ISR). Use this attribute if the preamble of the ISR prologue should always read

```
push  __zero_reg__
push  __tmp_reg__
in    __tmp_reg__, __SREG__
push  __tmp_reg__
clr   __zero_reg__
```

and accordingly for the postamble of the epilogue — no matter whether the mentioned registers are actually used in the ISR or not. Situations where you might want to use this attribute include:

- Code that (effectively) clobbers bits of `SREG` other than the `I`-flag by writing to the memory location of `SREG`.
- Code that uses inline assembler to jump to a different function which expects (parts of) the prologue code as outlined above to be present.

To disable `__gcc_isr` generation for the whole compilation unit, there is option `-mno-gas-isr-prologues`, see Section 3.20.6 [AVR Options], page 388.

`OS_main`
`OS_task`
: On AVR, functions with the `OS_main` or `OS_task` attribute do not save/restore any call-saved register in their prologue/epilogue.

The `OS_main` attribute can be used when there *is guarantee* that interrupts are disabled at the time when the function is entered. This saves resources when the stack pointer has to be changed to set up a frame for local variables.

The `OS_task` attribute can be used when there is *no guarantee* that interrupts are disabled at that time when the function is entered like for, e.g. task functions in a multi-threading operating system. In that case, changing the stack pointer register is guarded by save/clear/restore of the global interrupt enable flag.

The differences to the `naked` function attribute are:

- naked functions do not have a return instruction whereas OS_main and OS_task functions have a RET or RETI return instruction.
- naked functions do not set up a frame for local variables or a frame pointer whereas OS_main and OS_task do this as needed.

6.4.1.7 Blackfin Function Attributes

These function attributes are supported by the Blackfin back end:

exception_handler
: Use this attribute on the Blackfin to indicate that the specified function is an exception handler. The compiler generates function entry and exit sequences suitable for use in an exception handler when this attribute is present.

interrupt_handler
: Use this attribute to indicate that the specified function is an interrupt handler. The compiler generates function entry and exit sequences suitable for use in an interrupt handler when this attribute is present.

kspisusp
: When used together with interrupt_handler, exception_handler or nmi_handler, code is generated to load the stack pointer from the USP register in the function prologue.

l1_text
: This attribute specifies a function to be placed into L1 Instruction SRAM. The function is put into a specific section named .l1.text. With -mfdpic, function calls with a such function as the callee or caller uses inlined PLT.

l2
: This attribute specifies a function to be placed into L2 SRAM. The function is put into a specific section named .l2.text. With -mfdpic, callers of such functions use an inlined PLT.

longcall
shortcall
: The longcall attribute indicates that the function might be far away from the call site and require a different (more expensive) calling sequence. The shortcall attribute indicates that the function is always close enough for the shorter calling sequence to be used. These attributes override the -mlongcall switch.

nesting
: Use this attribute together with interrupt_handler, exception_handler or nmi_handler to indicate that the function entry code should enable nested interrupts or exceptions.

nmi_handler
: Use this attribute on the Blackfin to indicate that the specified function is an NMI handler. The compiler generates function entry and exit sequences suitable for use in an NMI handler when this attribute is present.

saveall
: Use this attribute to indicate that all registers except the stack pointer should be saved in the prologue regardless of whether they are used or not.

6.4.1.8 BPF Function Attributes

These function attributes are supported by the BPF back end:

`kernel_helper`
: use this attribute to indicate the specified function declaration is a kernel helper. The helper function is passed as an argument to the attribute. Example:

```
int bpf_probe_read (void *dst, int size, const void *unsafe_ptr)
  __attribute__ ((kernel_helper (4)));
```

`naked`
: This attribute allows the compiler to construct the requisite function declaration, while allowing the body of the function to be assembly code. The specified function will not have prologue/epilogue sequences generated by the compiler. Only basic `asm` statements can safely be included in naked functions (see Section 6.11.1 [Basic Asm], page 753). While using extended `asm` or a mixture of basic `asm` and C code may appear to work, they cannot be depended upon to work reliably and are not supported.

6.4.1.9 C-SKY Function Attributes

These function attributes are supported by the C-SKY back end:

`interrupt`
`isr`
: Use these attributes to indicate that the specified function is an interrupt handler. The compiler generates function entry and exit sequences suitable for use in an interrupt handler when either of these attributes are present.

Use of these options requires the `-mistack` command-line option to enable support for the necessary interrupt stack instructions. They are ignored with a warning otherwise. See Section 3.20.10 [C-SKY Options], page 406.

`naked`
: This attribute allows the compiler to construct the requisite function declaration, while allowing the body of the function to be assembly code. The specified function will not have prologue/epilogue sequences generated by the compiler. Only basic `asm` statements can safely be included in naked functions (see Section 6.11.1 [Basic Asm], page 753). While using extended `asm` or a mixture of basic `asm` and C code may appear to work, they cannot be depended upon to work reliably and are not supported.

6.4.1.10 Epiphany Function Attributes

These function attributes are supported by the Epiphany back end:

`disinterrupt`
: This attribute causes the compiler to emit instructions to disable interrupts for the duration of the given function.

`forwarder_section`
: This attribute modifies the behavior of an interrupt handler. The interrupt handler may be in external memory which cannot be reached by a branch instruction, so generate a local memory trampoline to transfer control. The single parameter identifies the section where the trampoline is placed.

`interrupt`

Use this attribute to indicate that the specified function is an interrupt handler. The compiler generates function entry and exit sequences suitable for use in an interrupt handler when this attribute is present. It may also generate a special section with code to initialize the interrupt vector table.

On Epiphany targets one or more optional parameters can be added like this:

```
void __attribute__ ((interrupt ("dma0, dma1"))) universal_dma_handler ();
```

Permissible values for these parameters are: `reset`, `software_exception`, `page_miss`, `timer0`, `timer1`, `message`, `dma0`, `dma1`, `wand` and `swi`. Multiple parameters indicate that multiple entries in the interrupt vector table should be initialized for this function, i.e. for each parameter *name*, a jump to the function is emitted in the section ivt_entry_*name*. The parameter(s) may be omitted entirely, in which case no interrupt vector table entry is provided.

Note that interrupts are enabled inside the function unless the `disinterrupt` attribute is also specified.

The following examples are all valid uses of these attributes on Epiphany targets:

```
void __attribute__ ((interrupt)) universal_handler ();
void __attribute__ ((interrupt ("dma1"))) dma1_handler ();
void __attribute__ ((interrupt ("dma0, dma1")))
  universal_dma_handler ();
void __attribute__ ((interrupt ("timer0"), disinterrupt))
  fast_timer_handler ();
void __attribute__ ((interrupt ("dma0, dma1"),
                     forwarder_section ("tramp")))
  external_dma_handler ();
```

`long_call`
`short_call`

These attributes specify how a particular function is called. These attributes override the `-mlong-calls` (see Section 3.20.2 [Adapteva Epiphany Options], page 356) command-line switch and `#pragma long_calls` settings.

6.4.1.11 H8/300 Function Attributes

These function attributes are available for H8/300 targets:

`function_vector`

Use this attribute on the H8/300, H8/300H, and H8S to indicate that the specified function should be called through the function vector. Calling a function through the function vector reduces code size; however, the function vector has a limited size (maximum 128 entries on the H8/300 and 64 entries on the H8/300H and H8S) and shares space with the interrupt vector.

`interrupt_handler`

Use this attribute on the H8/300, H8/300H, and H8S to indicate that the specified function is an interrupt handler. The compiler generates function entry and exit sequences suitable for use in an interrupt handler when this attribute is present.

`saveall` Use this attribute on the H8/300, H8/300H, and H8S to indicate that all registers except the stack pointer should be saved in the prologue regardless of whether they are used or not.

6.4.1.12 IA-64 Function Attributes

These function attributes are supported on IA-64 targets:

`syscall_linkage`
: This attribute is used to modify the IA-64 calling convention by marking all input registers as live at all function exits. This makes it possible to restart a system call after an interrupt without having to save/restore the input registers. This also prevents kernel data from leaking into application code.

`version_id`
: This IA-64 HP-UX attribute, attached to a global variable or function, renames a symbol to contain a version string, thus allowing for function level versioning. HP-UX system header files may use function level versioning for some system calls.

```
extern int foo () __attribute__((version_id ("20040821")));
```

Calls to `foo` are mapped to calls to `foo{20040821}`.

6.4.1.13 LoongArch Function Attributes

The following attributes are supported by LoongArch end:

`target (option,...)`
: The following target-specific function attributes are available for the LoongArch target. These options mirror the behavior of similar command-line options (see Section 3.20.23 [LoongArch Options], page 434), but on a per-function basis.

`strict-align`
`no-strict-align`
: `strict-align` indicates that the compiler should not assume that unaligned memory references are handled by the system. To allow the compiler to assume that aligned memory references are handled by the system, the inverse attribute `no-strict-align` can be specified. The behavior is same as for the command-line option `-mstrict-align` and `-mno-strict-align`.

`cmodel=` Indicates that code should be generated for a particular code model for this function. The behavior and permissible arguments are the same as for the command-line option `-mcmodel=`.

`arch=` Specifies the architecture version and architectural extensions to use for this function. The behavior and permissible arguments are the same as for the `-march=` command-line option.

`tune=` Specifies the core for which to tune the performance of this function. The behavior and permissible arguments are the same as for the `-mtune=` command-line option.

`lsx`
`no-lsx`
: `lsx` indicates that vector instruction generation is allowed (not allowed) when compiling the function. The behavior is same as for the command-line option `-mlsx` and `-mno-lsx`.

`lasx`
`no-lasx`
: `lasx` indicates that lasx instruction generation is allowed (not allowed) when compiling the function. The behavior is slightly different from the command-line option `-mno-lasx`. Example:

```
test.c:
typedef int v4i32 __attribute__ ((vector_size(16), aligned(16)));

v4i32 a, b, c;
#ifdef WITH_ATTR
__attribute__ ((target("no-lasx"))) void
#else
void
#endif
test ()
{
  c = a + b;
}
```

```
$ gcc test.c -o test.s -O2 -mlasx -DWITH_ATTR
```

Compiled as above, 128-bit vectorization is possible. But the following method cannot perform 128-bit vectorization.

```
$ gcc test.c -o test.s -O2 -mlasx -mno-lasx
```

`recipe`
`no-recipe`
: `recipe` indicates that frecipe.{s/d} and frsqrt.{s/d}instruction generation is allowed (not allowed) when compiling the function. The behavior is same as for the command-line option `-mrecipe` and `-mno-recipe`.

`div32`
`no-div32`
: `div32` determines whether div.w[u] and mod.w[u] instructions on 64-bit machines are evaluated based only on the lower 32 bits of the input registers. `-mdiv32` and `-mno-div32`.

`lam-bh`
`no-lam-bh`
: `lam-bh` indicates that am{swap/add}[_db].{b/h} instruction generation is allowed (not allowed) when compiling the function. The behavior is same as for the command-line option `-mlam-bh` and `-mno-lam-bh`.

`lamcas`
`no-lamcas`
: `lamcas` indicates that amcas[_db].{b/h/w/d} instruction generation is allowed (not allowed) when compiling the function. The behavior is same as for the command-line option `-mlamcas` and `-mno-lamcas`.

`scq`
`no-scq` `scq` indicates that sc.q instruction generation is allowed (not allowed) when compiling the function. The behavior is same as for the command-line option `-mscq` and `-mno-scq`.

`ld-seq-sa`
`no-ld-seq-sa`
`ld-seq-sa` indicates that whether need load-load barries (dbar 0x700) `-mld-seq-sa` and `-mno-ld-seq-sa`.

Multiple target function attributes can be specified by separating them with a comma. For example:

```
__attribute__((target("arch=la64v1.1,lasx")))
int
foo (int a)
{
  return a + 5;
}
```

is valid and compiles function `foo` for LA64V1.1 with `lasx`.

Inlining rules

Specifying target attributes on individual functions or performing link-time optimization across translation units compiled with different target options can affect function inlining rules:

In particular, a caller function can inline a callee function only if the architectural features available to the callee are a subset of the features available to the caller.

Note that when the callee function does not have the always_inline attribute, it will not be inlined if the code model of the caller function is different from the code model of the callee function.

`target_clones (string,...)`
Like attribute `target`, these options also reflect the behavior of similar command line options.

`string` can take the following values:

- default
- strict-align
- arch=
- lsx
- lasx
- frecipe
- div32
- lam-bh
- lamcas
- scq
- ld-seq-sa

You can set the priority of attributes in target_clones (except `default`). For example:

```
__attribute__((target_clones ("default","arch=la64v1.1","lsx;priority=1")))
int
foo (int a)
{
  return a + 5;
}
```

The priority is from low to high:

- default
- arch=loongarch64
- strict-align
- frecipe = div32 = lam-bh = lamcas = scq = ld-seq-sa
- lsx
- arch=la64v1.0
- arch=la64v1.1
- lasx

Note that the option values on the gcc command line are not considered when calculating the priority.

If a priority is set for a feature in target_clones, then the priority of this feature will be higher than `lasx`.

For example:

```
__attribute__((target_clones ("default","arch=la64v1.1","lsx;priority=1")))
int
foo (int a)
{
  return a + 5;
}
```

In this test case, the priority of `lsx` is higher than that of `arch=la64v1.1`.

If the same priority is explicitly set for two features, the priority is still calculated according to the priority list above.

For example:

```
__attribute__((target_clones ("default","arch=la64v1.1;priority=1","lsx;priority=1")))
int
foo (int a)
{
  return a + 5;
}
```

In this test case, the priority of `arch=la64v1.1;priority=1` is higher than that of `lsx;priority=1`.

`target_version (string)`

Support attributes and priorities are the same as `target_clones`. Note that this attribute requires GLIBC2.38 and newer that support HWCAP.

For example:

`test1.C`

```
__attribute__((target_clones ("default","arch=la64v1.1","lsx;priority=1")))
```

```
int
foo (int a)
{
  return a + 5;
}
```

test2.C

```
__attribute__((target_version ("default")))
int
foo (int a)
{
  return a + 5;
}
__attribute__((target_version ("arch=la64v1.1")))
int
foo (int a)
{
  return a + 5;
}
__attribute__((target_version ("lsx;priority=1")))
int
foo (int a)
{
  return a + 5;
}
```

The implementations of `test1.C` and `test2.C` are equivalent.

6.4.1.14 M32C Function Attributes

These function attributes are supported by the M32C back end:

`bank_switch`
: When added to an interrupt handler with the M32C port, causes the prologue and epilogue to use bank switching to preserve the registers rather than saving them on the stack.

`fast_interrupt`
: Use this attribute on the M32C port to indicate that the specified function is a fast interrupt handler. This is just like the `interrupt` attribute, except that `freit` is used to return instead of `reit`.

`function_vector`
: On M16C/M32C targets, the `function_vector` attribute declares a special page subroutine call function. Use of this attribute reduces the code size by 2 bytes for each call generated to the subroutine. The argument to the attribute is the vector number entry from the special page vector table which contains the 16 low-order bits of the subroutine's entry address. Each vector table has special page number (18 to 255) that is used in `jsrs` instructions. Jump addresses of the routines are generated by adding 0x0F0000 (in case of M16C targets) or 0xFF0000 (in case of M32C targets), to the 2-byte addresses set in the vector table. Therefore you need to ensure that all the special page vector routines should get mapped within the address range 0x0F0000 to 0x0FFFFF (for M16C) and 0xFF0000 to 0xFFFFFF (for M32C).

  In the following example 2 bytes are saved for each call to function `foo`.

```
void foo (void) __attribute__((function_vector(0x18)));
```

```
void foo (void)
{
}

void bar (void)
{
    foo();
}
```

If functions are defined in one file and are called in another file, then be sure to write this declaration in both files.

This attribute is ignored for R8C target.

`interrupt`

Use this attribute to indicate that the specified function is an interrupt handler. The compiler generates function entry and exit sequences suitable for use in an interrupt handler when this attribute is present.

6.4.1.15 M32R/D Function Attributes

These function attributes are supported by the M32R/D back end:

`interrupt`

Use this attribute to indicate that the specified function is an interrupt handler. The compiler generates function entry and exit sequences suitable for use in an interrupt handler when this attribute is present.

`model (`*`model-name`*`)`

On the M32R/D, use this attribute to set the addressability of an object, and of the code generated for a function. The identifier *model-name* is one of `small`, `medium`, or `large`, representing each of the code models.

Small model objects live in the lower 16MB of memory (so that their addresses can be loaded with the `ld24` instruction), and are callable with the `bl` instruction.

Medium model objects may live anywhere in the 32-bit address space (the compiler generates `seth/add3` instructions to load their addresses), and are callable with the `bl` instruction.

Large model objects may live anywhere in the 32-bit address space (the compiler generates `seth/add3` instructions to load their addresses), and may not be reachable with the `bl` instruction (the compiler generates the much slower `seth/add3/jl` instruction sequence).

6.4.1.16 m68k Function Attributes

These function attributes are supported by the m68k back end:

`interrupt`
`interrupt_handler`

Use this attribute to indicate that the specified function is an interrupt handler. The compiler generates function entry and exit sequences suitable for use in an interrupt handler when this attribute is present. Either name may be used.

`interrupt_thread`
: Use this attribute on fido, a subarchitecture of the m68k, to indicate that the specified function is an interrupt handler that is designed to run as a thread. The compiler omits generate prologue/epilogue sequences and replaces the return instruction with a `sleep` instruction. This attribute is available only on fido.

6.4.1.17 MCORE Function Attributes

These function attributes are supported by the MCORE back end:

`naked`
: This attribute allows the compiler to construct the requisite function declaration, while allowing the body of the function to be assembly code. The specified function will not have prologue/epilogue sequences generated by the compiler. Only basic `asm` statements can safely be included in naked functions (see Section 6.11.1 [Basic Asm], page 753). While using extended `asm` or a mixture of basic `asm` and C code may appear to work, they cannot be depended upon to work reliably and are not supported.

6.4.1.18 MicroBlaze Function Attributes

These function attributes are supported on MicroBlaze targets:

`save_volatiles`
: Use this attribute to indicate that the function is an interrupt handler. All volatile registers (in addition to non-volatile registers) are saved in the function prologue. If the function is a leaf function, only volatiles used by the function are saved. A normal function return is generated instead of a return from interrupt.

`break_handler`
: Use this attribute to indicate that the specified function is a break handler. The compiler generates function entry and exit sequences suitable for use in an break handler when this attribute is present. The return from `break_handler` is done through the `rtbd` instead of `rtsd`.

```
void f () __attribute__ ((break_handler));
```

`interrupt_handler`
`fast_interrupt`
: These attributes indicate that the specified function is an interrupt handler. Use the `fast_interrupt` attribute to indicate handlers used in low-latency interrupt mode, and `interrupt_handler` for interrupts that do not use low-latency handlers. In both cases, GCC emits appropriate prologue code and generates a return from the handler using `rtid` instead of `rtsd`.

6.4.1.19 Microsoft Windows Function Attributes

The following attributes are available on Microsoft Windows and Symbian OS targets.

`dllexport`
: On Microsoft Windows targets and Symbian OS targets the `dllexport` attribute causes the compiler to provide a global pointer to a pointer in a DLL,

so that it can be referenced with the `dllimport` attribute. On Microsoft Windows targets, the pointer name is formed by combining `_imp__` and the function or variable name.

You can use `__declspec(dllexport)` as a synonym for `__attribute__ ((dllexport))` for compatibility with other compilers.

On systems that support the `visibility` attribute, this attribute also implies "default" visibility. It is an error to explicitly specify any other visibility.

GCC's default behavior is to emit all inline functions with the `dllexport` attribute. Since this can cause object file-size bloat, you can use `-fno-keep-inline-dllexport`, which tells GCC to ignore the attribute for inlined functions unless the `-fkeep-inline-functions` flag is used instead.

The attribute is ignored for undefined symbols.

When applied to C++ classes, the attribute marks defined non-inlined member functions and static data members as exports. Static consts initialized in-class are not marked unless they are also defined out-of-class.

For Microsoft Windows targets there are alternative methods for including the symbol in the DLL's export table such as using a `.def` file with an `EXPORTS` section or, with GNU ld, using the `--export-all` linker flag.

`dllimport`

On Microsoft Windows and Symbian OS targets, the `dllimport` attribute causes the compiler to reference a function or variable via a global pointer to a pointer that is set up by the DLL exporting the symbol. The attribute implies `extern`. On Microsoft Windows targets, the pointer name is formed by combining `_imp__` and the function or variable name.

You can use `__declspec(dllimport)` as a synonym for `__attribute__ ((dllimport))` for compatibility with other compilers.

On systems that support the `visibility` attribute, this attribute also implies "default" visibility. It is an error to explicitly specify any other visibility.

Currently, the attribute is ignored for inlined functions. If the attribute is applied to a symbol *definition*, an error is reported. If a symbol previously declared `dllimport` is later defined, the attribute is ignored in subsequent references, and a warning is emitted. The attribute is also overridden by a subsequent declaration as `dllexport`.

When applied to C++ classes, the attribute marks non-inlined member functions and static data members as imports. However, the attribute is ignored for virtual methods to allow creation of vtables using thunks.

On the SH Symbian OS target the `dllimport` attribute also has another affect—it can cause the vtable and run-time type information for a class to be exported. This happens when the class has a dllimported constructor or a non-inline, non-pure virtual function and, for either of those two conditions, the class also has an inline constructor or destructor and has a key function that is defined in the current translation unit.

For Microsoft Windows targets the use of the `dllimport` attribute on functions is not necessary, but provides a small performance benefit by eliminating a thunk in the DLL. The use of the `dllimport` attribute on imported variables can be avoided by passing the `--enable-auto-import` switch to the GNU linker. As with functions, using the attribute for a variable eliminates a thunk in the DLL.

One drawback to using this attribute is that a pointer to a *variable* marked as `dllimport` cannot be used as a constant address. However, a pointer to a *function* with the `dllimport` attribute can be used as a constant initializer; in this case, the address of a stub function in the import lib is referenced. On Microsoft Windows targets, the attribute can be disabled for functions by setting the `-mnop-fun-dllimport` flag.

6.4.1.20 MIPS Function Attributes

These function attributes are supported by the MIPS back end:

`interrupt`

Use this attribute to indicate that the specified function is an interrupt handler. The compiler generates function entry and exit sequences suitable for use in an interrupt handler when this attribute is present. An optional argument is supported for the interrupt attribute which allows the interrupt mode to be described. By default GCC assumes the external interrupt controller (EIC) mode is in use, this can be explicitly set using `eic`. When interrupts are non-masked then the requested Interrupt Priority Level (IPL) is copied to the current IPL which has the effect of only enabling higher priority interrupts. To use vectored interrupt mode use the argument `vector=[sw0|sw1|hw0|hw1|hw2|hw3|hw4|hw5]`, this will change the behavior of the non-masked interrupt support and GCC will arrange to mask all interrupts from sw0 up to and including the specified interrupt vector.

You can use the following attributes to modify the behavior of an interrupt handler:

`use_shadow_register_set`

Assume that the handler uses a shadow register set, instead of the main general-purpose registers. An optional argument `intstack` is supported to indicate that the shadow register set contains a valid stack pointer.

`keep_interrupts_masked`

Keep interrupts masked for the whole function. Without this attribute, GCC tries to reenable interrupts for as much of the function as it can.

`use_debug_exception_return`

Return using the `deret` instruction. Interrupt handlers that don't have this attribute return using `eret` instead.

You can use any combination of these attributes, as shown below:

```
void __attribute__ ((interrupt)) v0 ();
void __attribute__ ((interrupt, use_shadow_register_set)) v1 ();
void __attribute__ ((interrupt, keep_interrupts_masked)) v2 ();
void __attribute__ ((interrupt, use_debug_exception_return)) v3 ();
```

```
void __attribute__ ((interrupt, use_shadow_register_set,
                     keep_interrupts_masked)) v4 ();
void __attribute__ ((interrupt, use_shadow_register_set,
                     use_debug_exception_return)) v5 ();
void __attribute__ ((interrupt, keep_interrupts_masked,
                     use_debug_exception_return)) v6 ();
void __attribute__ ((interrupt, use_shadow_register_set,
                     keep_interrupts_masked,
                     use_debug_exception_return)) v7 ();
void __attribute__ ((interrupt("eic"))) v8 ();
void __attribute__ ((interrupt("vector=hw3"))) v9 ();
```

`long_call`
`short_call`
`near`
`far`
These attributes specify how a particular function is called on MIPS. The attributes override the `-mlong-calls` (see Section 3.20.29 [MIPS Options], page 449) command-line switch. The `long_call` and `far` attributes are synonyms, and cause the compiler to always call the function by first loading its address into a register, and then using the contents of that register. The `short_call` and `near` attributes are synonyms, and have the opposite effect; they specify that non-PIC calls should be made using the more efficient `jal` instruction.

`mips16`
`nomips16`

On MIPS targets, you can use the `mips16` and `nomips16` function attributes to locally select or turn off MIPS16 code generation. A function with the `mips16` attribute is emitted as MIPS16 code, while MIPS16 code generation is disabled for functions with the `nomips16` attribute. These attributes override the `-mips16` and `-mno-mips16` options on the command line (see Section 3.20.29 [MIPS Options], page 449).

When compiling files containing mixed MIPS16 and non-MIPS16 code, the preprocessor symbol `__mips16` reflects the setting on the command line, not that within individual functions. Mixed MIPS16 and non-MIPS16 code may interact badly with some GCC extensions such as `__builtin_apply` (see Section 7.5 [Constructing Calls], page 845).

`micromips, MIPS`
`nomicromips, MIPS`
On MIPS targets, you can use the `micromips` and `nomicromips` function attributes to locally select or turn off microMIPS code generation. A function with the `micromips` attribute is emitted as microMIPS code, while microMIPS code generation is disabled for functions with the `nomicromips` attribute. These attributes override the `-mmicromips` and `-mno-micromips` options on the command line (see Section 3.20.29 [MIPS Options], page 449).

When compiling files containing mixed microMIPS and non-microMIPS code, the preprocessor symbol `__mips_micromips` reflects the setting on the command line, not that within individual functions. Mixed microMIPS and non-microMIPS code may interact badly with some GCC extensions such as `__builtin_apply` (see Section 7.5 [Constructing Calls], page 845).

`nocompression`
On MIPS targets, you can use the `nocompression` function attribute to locally turn off MIPS16 and microMIPS code generation. This attribute overrides the `-mips16` and `-mmicromips` options on the command line (see Section 3.20.29 [MIPS Options], page 449).

`use_hazard_barrier_return`
This function attribute instructs the compiler to generate a hazard barrier return that clears all execution and instruction hazards while returning, instead of generating a normal return instruction.

`code_readable`
For MIPS targets that support PC-relative addressing modes, this attribute can be used to control how an object is addressed. The attribute takes a single optional argument:

‘`no`’ The function should not read the instruction stream as data.

‘`yes`’ The function can read the instruction stream as data.

‘`pcrel`’ The function can read the instruction stream in a pc-relative mode.

If there is no argument supplied, the default of `"yes"` applies.

6.4.1.21 MSP430 Function Attributes

These function attributes are supported by the MSP430 back end:

`critical` Critical functions disable interrupts upon entry and restore the previous interrupt state upon exit. Critical functions cannot also have the `naked`, `reentrant` or `interrupt` attributes.

The MSP430 hardware ensures that interrupts are disabled on entry to `interrupt` functions, and restores the previous interrupt state on exit. The `critical` attribute is therefore redundant on `interrupt` functions.

`interrupt`
Use this attribute to indicate that the specified function is an interrupt handler. The compiler generates function entry and exit sequences suitable for use in an interrupt handler when this attribute is present.

You can provide an argument to the interrupt attribute which specifies a name or number. If the argument is a number it indicates the slot in the interrupt vector table (0 - 31) to which this handler should be assigned. If the argument is a name it is treated as a symbolic name for the vector slot. These names should match up with appropriate entries in the linker script. By default the names `watchdog` for vector 26, `nmi` for vector 30 and `reset` for vector 31 are recognized.

`naked` This attribute allows the compiler to construct the requisite function declaration, while allowing the body of the function to be assembly code. The specified function will not have prologue/epilogue sequences generated by the compiler.

Only basic `asm` statements can safely be included in naked functions (see Section 6.11.1 [Basic Asm], page 753). While using extended `asm` or a mixture of basic `asm` and C code may appear to work, they cannot be depended upon to work reliably and are not supported.

`reentrant`
: Reentrant functions disable interrupts upon entry and enable them upon exit. Reentrant functions cannot also have the `naked` or `critical` attributes. They can have the `interrupt` attribute.

`wakeup`
: This attribute only applies to interrupt functions. It is silently ignored if applied to a non-interrupt function. A wakeup interrupt function will rouse the processor from any low-power state that it might be in when the function exits.

`lower`
`upper`
`either`
: On the MSP430 target these attributes can be used to specify whether the function or variable should be placed into low memory, high memory, or the placement should be left to the linker to decide. The attributes are only significant if compiling for the MSP430X architecture in the large memory model.

The attributes work in conjunction with a linker script that has been augmented to specify where to place sections with a `.lower` and a `.upper` prefix. So, for example, as well as placing the `.data` section, the script also specifies the placement of a `.lower.data` and a `.upper.data` section. The intention is that `lower` sections are placed into a small but easier to access memory region and the upper sections are placed into a larger, but slower to access, region.

The `either` attribute is special. It tells the linker to place the object into the corresponding `lower` section if there is room for it. If there is insufficient room then the object is placed into the corresponding `upper` section instead. Note that the placement algorithm is not very sophisticated. It does not attempt to find an optimal packing of the `lower` sections. It just makes one pass over the objects and does the best that it can. Using the `-ffunction-sections` and `-fdata-sections` command-line options can help the packing, however, since they produce smaller, easier to pack regions.

6.4.1.22 NDS32 Function Attributes

These function attributes are supported by the NDS32 back end:

`exception`
: Use this attribute on the NDS32 target to indicate that the specified function is an exception handler. The compiler will generate corresponding sections for use in an exception handler.

`interrupt`
: On NDS32 target, this attribute indicates that the specified function is an interrupt handler. The compiler generates corresponding sections for use in an interrupt handler. You can use the following attributes to modify the behavior:

`nested` This interrupt service routine is interruptible.

`not_nested`
: This interrupt service routine is not interruptible.

`nested_ready`
: This interrupt service routine is interruptible after `PSW.GIE` (global interrupt enable) is set. This allows interrupt service routine to finish some short critical code before enabling interrupts.

`save_all`
: The system will help save all registers into stack before entering interrupt handler.

`partial_save`
: The system will help save caller registers into stack before entering interrupt handler.

`naked`
: This attribute allows the compiler to construct the requisite function declaration, while allowing the body of the function to be assembly code. The specified function will not have prologue/epilogue sequences generated by the compiler. Only basic `asm` statements can safely be included in naked functions (see Section 6.11.1 [Basic Asm], page 753). While using extended `asm` or a mixture of basic `asm` and C code may appear to work, they cannot be depended upon to work reliably and are not supported.

`reset`
: Use this attribute on the NDS32 target to indicate that the specified function is a reset handler. The compiler will generate corresponding sections for use in a reset handler. You can use the following attributes to provide extra exception handling:

`nmi`
: Provide a user-defined function to handle NMI exception.

`warm`
: Provide a user-defined function to handle warm reset exception.

6.4.1.23 Nvidia PTX Function Attributes

These function attributes are supported by the Nvidia PTX back end:

`kernel`
: This attribute indicates that the corresponding function should be compiled as a kernel function, which can be invoked from the host via the CUDA RT library. By default functions are only callable only from other PTX functions.

Kernel functions must have `void` return type.

6.4.1.24 PowerPC Function Attributes

These function attributes are supported by the PowerPC back end:

`longcall`
`shortcall`
: The `longcall` attribute indicates that the function might be far away from the call site and require a different (more expensive) calling sequence. The `shortcall` attribute indicates that the function is always close enough for the shorter calling sequence to be used. These attributes override both the `-mlongcall` switch and the `#pragma longcall` setting.

See Section 3.20.42 [RS/6000 and PowerPC Options], page 493, for more information on whether long calls are necessary.

`target (`*options*`)`

As discussed in Section 6.4.1.1 [Common Function Attributes], page 622, this attribute allows specification of target-specific compilation options.

On the PowerPC, the following options are allowed:

'altivec'
'no-altivec'
: Generate code that uses (does not use) AltiVec instructions. In 32-bit code, you cannot enable AltiVec instructions unless **-mabi=altivec** is used on the command line.

'cmpb'
'no-cmpb'
: Generate code that uses (does not use) the compare bytes instruction implemented on the POWER6 processor and other processors that support the PowerPC V2.05 architecture.

'dlmzb'
'no-dlmzb'
: Generate code that uses (does not use) the string-search 'dlmzb' instruction on the IBM 405, 440, 464 and 476 processors. This instruction is generated by default when targeting those processors.

'fprnd'
'no-fprnd'
: Generate code that uses (does not use) the FP round to integer instructions implemented on the POWER5+ processor and other processors that support the PowerPC V2.03 architecture.

'hard-dfp'
'no-hard-dfp'
: Generate code that uses (does not use) the decimal floating-point instructions implemented on some POWER processors.

'isel'
'no-isel'
: Generate code that uses (does not use) ISEL instruction.

'mfcrf'
'no-mfcrf'
: Generate code that uses (does not use) the move from condition register field instruction implemented on the POWER4 processor and other processors that support the PowerPC V2.01 architecture.

'mulhw'
'no-mulhw'
: Generate code that uses (does not use) the half-word multiply and multiply-accumulate instructions on the IBM 405, 440, 464 and 476 processors. These instructions are generated by default when targeting those processors.

'multiple'
'no-multiple'
: Generate code that uses (does not use) the load multiple word instructions and the store multiple word instructions.

'update'
'no-update'
Generate code that uses (does not use) the load or store instructions that update the base register to the address of the calculated memory location.

'popcntb'
'no-popcntb'
Generate code that uses (does not use) the popcount and double-precision FP reciprocal estimate instruction implemented on the POWER5 processor and other processors that support the PowerPC V2.02 architecture.

'popcntd'
'no-popcntd'
Generate code that uses (does not use) the popcount instruction implemented on the POWER7 processor and other processors that support the PowerPC V2.06 architecture.

'powerpc-gfxopt'
'no-powerpc-gfxopt'
Generate code that uses (does not use) the optional PowerPC architecture instructions in the Graphics group, including floating-point select.

'powerpc-gpopt'
'no-powerpc-gpopt'
Generate code that uses (does not use) the optional PowerPC architecture instructions in the General Purpose group, including floating-point square root.

'recip-precision'
'no-recip-precision'
Assume (do not assume) that the reciprocal estimate instructions provide higher-precision estimates than is mandated by the PowerPC ABI.

'string'
'no-string'
Generate code that uses (does not use) the load string instructions and the store string word instructions to save multiple registers and do small block moves.

'vsx'
'no-vsx'
Generate code that uses (does not use) vector/scalar (VSX) instructions, and also enable the use of built-in functions that allow more direct access to the VSX instruction set. In 32-bit code, you cannot enable VSX or AltiVec instructions unless `-mabi=altivec` is used on the command line.

'friz'
'no-friz' Generate (do not generate) the friz instruction when the -funsafe-math-optimizations option is used to optimize rounding a floating-point value to 64-bit integer and back to floating point. The friz instruction does not return the same value if the floating-point number is too large to fit in an integer.

'avoid-indexed-addresses'
'no-avoid-indexed-addresses'
Generate code that tries to avoid (not avoid) the use of indexed load or store instructions.

'paired'
'no-paired'
Generate code that uses (does not use) the generation of PAIRED simd instructions.

'longcall'
'no-longcall'
Generate code that assumes (does not assume) that all calls are far away so that a longer more expensive calling sequence is required.

'cpu=*CPU*' Specify the architecture to generate code for when compiling the function. If you select the target("cpu=power7") attribute when generating 32-bit code, VSX and AltiVec instructions are not generated unless you use the -mabi=altivec option on the command line.

'tune=*TUNE*'
Specify the architecture to tune for when compiling the function. If you do not specify the target("tune=*TUNE*") attribute and you do specify the target("cpu=*CPU*") attribute, compilation tunes for the *CPU* architecture, and not the default tuning specified on the command line.

On the PowerPC, the inliner does not inline a function that has different target options than the caller, unless the callee has a subset of the target options of the caller.

6.4.1.25 RISC-V Function Attributes

These function attributes are supported by the RISC-V back end:

naked This attribute allows the compiler to construct the requisite function declaration, while allowing the body of the function to be assembly code. The specified function will not have prologue/epilogue sequences generated by the compiler. Only basic asm statements can safely be included in naked functions (see Section 6.11.1 [Basic Asm], page 753). While using extended asm or a mixture of basic asm and C code may appear to work, they cannot be depended upon to work reliably and are not supported.

`interrupt`

Use this attribute to indicate that the specified function is an interrupt handler. The compiler generates function entry and exit sequences suitable for use in an interrupt handler when this attribute is present.

You can specify the kind of interrupt to be handled by adding an optional parameter to the interrupt attribute like this:

```
void f (void) __attribute__ ((interrupt ("supervisor")));
```

Permissible values for this parameter are `supervisor`, `machine`, and `rnmi`. If there is no parameter, then it defaults to `machine`.

`riscv_vector_cc`

Use this attribute to force the function to use the vector calling convention variant.

```
void foo() __attribute__((riscv_vector_cc));
[[riscv::vector_cc]] void foo(); // For C++11 and C23
```

The following target-specific function attributes are available for the RISC-V target. For the most part, these options mirror the behavior of similar command-line options (see Section 3.20.40 [RISC-V Options], page 475), but on a per-function basis.

`arch=` Specifies the architecture version and architectural extensions to use for this function. The behavior and permissible arguments are the same as for the `-march=` command-line option, in addtion, it also support extension enablement list, a list of extension name and prefixed with `+`, like `arch=+zba` means enable `zba` extension. Multiple extension can be enabled by separating them with a comma. For example: `arch=+zba,+zbb`.

`tune=` Specifies the core for which to tune the performance of this function. The behavior and permissible arguments are the same as for the `-mtune=` command-line option.

`cpu=` Specifies the core for which to tune the performance of this function and also whose architectural features to use. The behavior and valid arguments are the same as for the `-mcpu=` command-line option.

The above target attributes can be specified as follows:

```
__attribute__((target("attr-string")))
int
f (int a)
{
  return a + 5;
}
```

where *`attr-string`* is one of the attribute strings specified above.

Multiple target function attributes can be specified by separating them with a semicolon. For example:

```
__attribute__((target("arch=+zba,+zbb;tune=rocket")))
int
foo (int a)
{
  return a + 5;
}
```

is valid and compiles function `foo` with `zba` and `zbb` extensions and tunes it for `rocket`.

6.4.1.26 RL78 Function Attributes

These function attributes are supported by the RL78 back end:

`interrupt`
`brk_interrupt`
: These attributes indicate that the specified function is an interrupt handler. The compiler generates function entry and exit sequences suitable for use in an interrupt handler when this attribute is present.

  Use `brk_interrupt` instead of `interrupt` for handlers intended to be used with the `BRK` opcode (i.e. those that must end with `RETB` instead of `RETI`).

`naked`
: This attribute allows the compiler to construct the requisite function declaration, while allowing the body of the function to be assembly code. The specified function will not have prologue/epilogue sequences generated by the compiler. Only basic `asm` statements can safely be included in naked functions (see Section 6.11.1 [Basic Asm], page 753). While using extended `asm` or a mixture of basic `asm` and C code may appear to work, they cannot be depended upon to work reliably and are not supported.

6.4.1.27 RX Function Attributes

These function attributes are supported by the RX back end:

`fast_interrupt`
: Use this attribute on the RX port to indicate that the specified function is a fast interrupt handler. This is just like the `interrupt` attribute, except that `freit` is used to return instead of `reit`.

`interrupt`
: Use this attribute to indicate that the specified function is an interrupt handler. The compiler generates function entry and exit sequences suitable for use in an interrupt handler when this attribute is present.

  On RX and RL78 targets, you may specify one or more vector numbers as arguments to the attribute, as well as naming an alternate table name. Parameters are handled sequentially, so one handler can be assigned to multiple entries in multiple tables. One may also pass the magic string `"$default"` which causes the function to be used for any unfilled slots in the current table.

  This example shows a simple assignment of a function to one vector in the default table (note that preprocessor macros may be used for chip-specific symbolic vector names):

```
void __attribute__ ((interrupt (5))) txd1_handler ();
```

  This example assigns a function to two slots in the default table (using preprocessor macros defined elsewhere) and makes it the default for the `dct` table:

```
void __attribute__ ((interrupt (RXD1_VECT,RXD2_VECT,"dct","$default")))
txd1_handler ();
```

`naked`
: This attribute allows the compiler to construct the requisite function declaration, while allowing the body of the function to be assembly code. The specified function will not have prologue/epilogue sequences generated by the compiler.

Only basic `asm` statements can safely be included in naked functions (see Section 6.11.1 [Basic Asm], page 753). While using extended `asm` or a mixture of basic `asm` and C code may appear to work, they cannot be depended upon to work reliably and are not supported.

`vector` This RX attribute is similar to the `interrupt` attribute, including its parameters, but does not make the function an interrupt-handler type function (i.e. it retains the normal C function calling ABI). See the `interrupt` attribute for a description of its arguments.

6.4.1.28 S/390 Function Attributes

These function attributes are supported on the S/390:

`hotpatch (`*`halfwords-before-function-label,halfwords-after-function-label`*`)`

On S/390 System z targets, you can use this function attribute to make GCC generate a "hot-patching" function prologue. If the `-mhotpatch=` command-line option is used at the same time, the `hotpatch` attribute takes precedence. The first of the two arguments specifies the number of halfwords to be added before the function label. A second argument can be used to specify the number of halfwords to be added after the function label. For both arguments the maximum allowed value is 1000000.

If both arguments are zero, hotpatching is disabled.

`target (`*`options`*`)`

As discussed in Section 6.4.1.1 [Common Function Attributes], page 622, this attribute allows specification of target-specific compilation options.

On S/390, the following options are supported:

'`arch=`'

'`tune=`'

'`stack-guard=`'
'`stack-size=`'
'`branch-cost=`'
'`warn-framesize=`'
'`backchain`'
'`no-backchain`'
'`hard-dfp`'
'`no-hard-dfp`'
'`hard-float`'
'`soft-float`'
'`htm`'
'`no-htm`'

'`vx`'
'`no-vx`'

'packed-stack'
'no-packed-stack'
'small-exec'
'no-small-exec'
'mvcle'
'no-mvcle'
'warn-dynamicstack'
'no-warn-dynamicstack'

The options work exactly like the S/390 specific command line options (without the prefix -m) except that they do not change any feature macros. For example,

```
target("no-vx")
```

does not undefine the __VEC__ macro.

6.4.1.29 SH Function Attributes

These function attributes are supported on the SH family of processors:

function_vector
: On SH2A targets, this attribute declares a function to be called using the TBR relative addressing mode. The argument to this attribute is the entry number of the same function in a vector table containing all the TBR relative addressable functions. For correct operation the TBR must be setup accordingly to point to the start of the vector table before any functions with this attribute are invoked. Usually a good place to do the initialization is the startup routine. The TBR relative vector table can have at max 256 function entries. The jumps to these functions are generated using a SH2A specific, non delayed branch instruction JSR/N @(disp8,TBR).

  In an application, for a function being called once, this attribute saves at least 8 bytes of code; and if other successive calls are being made to the same function, it saves 2 bytes of code per each of these calls.

interrupt_handler
: Use this attribute to indicate that the specified function is an interrupt handler. The compiler generates function entry and exit sequences suitable for use in an interrupt handler when this attribute is present.

nosave_low_regs
: Use this attribute on SH targets to indicate that an interrupt_handler function should not save and restore registers R0..R7. This can be used on SH3* and SH4* targets that have a second R0..R7 register bank for non-reentrant interrupt handlers.

renesas
: On SH targets this attribute specifies that the function or struct follows the Renesas ABI.

resbank
: On the SH2A target, this attribute enables the high-speed register saving and restoration using a register bank for interrupt_handler routines. Saving to the bank is performed automatically after the CPU accepts an interrupt that uses a register bank.

The nineteen 32-bit registers comprising general register R0 to R14, control register GBR, and system registers MACH, MACL, and PR and the vector table address offset are saved into a register bank. Register banks are stacked in first-in last-out (FILO) sequence. Restoration from the bank is executed by issuing a RESBANK instruction.

`sp_switch`
: Use this attribute on the SH to indicate an `interrupt_handler` function should switch to an alternate stack. It expects a string argument that names a global variable holding the address of the alternate stack.

```
void *alt_stack;
void f () __attribute__ ((interrupt_handler,
                          sp_switch ("alt_stack")));
```

`trap_exit`
: Use this attribute on the SH for an `interrupt_handler` to return using `trapa` instead of `rte`. This attribute expects an integer argument specifying the trap number to be used.

`trapa_handler`
: On SH targets this function attribute is similar to `interrupt_handler` but it does not save and restore all registers.

6.4.1.30 Symbian OS Function Attributes

See Section 6.4.1.19 [Microsoft Windows Function Attributes], page 671, for discussion of the `dllexport` and `dllimport` attributes.

6.4.1.31 V850 Function Attributes

The V850 back end supports these function attributes:

`interrupt`
`interrupt_handler`
: Use these attributes to indicate that the specified function is an interrupt handler. The compiler generates function entry and exit sequences suitable for use in an interrupt handler when either attribute is present.

6.4.1.32 Visium Function Attributes

These function attributes are supported by the Visium back end:

`interrupt`
: Use this attribute to indicate that the specified function is an interrupt handler. The compiler generates function entry and exit sequences suitable for use in an interrupt handler when this attribute is present.

6.4.1.33 x86 Function Attributes

These function attributes are supported by the x86 back end:

`cdecl`
: On the x86-32 targets, the `cdecl` attribute causes the compiler to assume that the calling function pops off the stack space used to pass arguments. This is useful to override the effects of the `-mrtd` switch.

`fastcall` On x86-32 targets, the `fastcall` attribute causes the compiler to pass the first argument (if of integral type) in the register ECX and the second argument (if of integral type) in the register EDX. Subsequent and other typed arguments are passed on the stack. The called function pops the arguments off the stack. If the number of arguments is variable all arguments are pushed on the stack.

`thiscall` On x86-32 targets, the `thiscall` attribute causes the compiler to pass the first argument (if of integral type) in the register ECX. Subsequent and other typed arguments are passed on the stack. The called function pops the arguments off the stack. If the number of arguments is variable all arguments are pushed on the stack. The `thiscall` attribute is intended for C++ non-static member functions. As a GCC extension, this calling convention can be used for C functions and for static member methods.

`ms_abi`
`sysv_abi`

On 32-bit and 64-bit x86 targets, you can use an ABI attribute to indicate which calling convention should be used for a function. The `ms_abi` attribute tells the compiler to use the Microsoft ABI, while the `sysv_abi` attribute tells the compiler to use the System V ELF ABI, which is used on GNU/Linux and other systems. The default is to use the Microsoft ABI when targeting Windows. On all other systems, the default is the System V ELF ABI.

Note, the `ms_abi` attribute for Microsoft Windows 64-bit targets currently requires the `-maccumulate-outgoing-args` option.

`callee_pop_aggregate_return (`*`number`*`)`

On x86-32 targets, you can use this attribute to control how aggregates are returned in memory. If the caller is responsible for popping the hidden pointer together with the rest of the arguments, specify *number* equal to zero. If callee is responsible for popping the hidden pointer, specify *number* equal to one.

The default x86-32 ABI assumes that the callee pops the stack for hidden pointer. However, on x86-32 Microsoft Windows targets, the compiler assumes that the caller pops the stack for hidden pointer.

`ms_hook_prologue`

On 32-bit and 64-bit x86 targets, you can use this function attribute to make GCC generate the "hot-patching" function prologue used in Win32 API functions in Microsoft Windows XP Service Pack 2 and newer.

`naked` This attribute allows the compiler to construct the requisite function declaration, while allowing the body of the function to be assembly code. The specified function will not have prologue/epilogue sequences generated by the compiler. Only basic `asm` statements can safely be included in naked functions (see Section 6.11.1 [Basic Asm], page 753). While using extended `asm` or a mixture of basic `asm` and C code may appear to work, they cannot be depended upon to work reliably and are not supported.

`regparm (`*`number`*`)`

On x86-32 targets, the `regparm` attribute causes the compiler to pass arguments number one to *number* if they are of integral type in registers EAX, EDX, and ECX instead of on the stack. Functions that take a variable number of arguments continue to be passed all of their arguments on the stack.

Beware that on some ELF systems this attribute is unsuitable for global functions in shared libraries with lazy binding (which is the default). Lazy binding sends the first call via resolving code in the loader, which might assume EAX, EDX and ECX can be clobbered, as per the standard calling conventions. Solaris 8 is affected by this. Systems with the GNU C Library version 2.1 or higher and FreeBSD are believed to be safe since the loaders there save EAX, EDX and ECX. (Lazy binding can be disabled with the linker or the loader if desired, to avoid the problem.)

`sseregparm`
: On x86-32 targets with SSE support, the `sseregparm` attribute causes the compiler to pass up to 3 floating-point arguments in SSE registers instead of on the stack. Functions that take a variable number of arguments continue to pass all of their floating-point arguments on the stack.

`force_align_arg_pointer`
: On x86 targets, the `force_align_arg_pointer` attribute may be applied to individual function definitions, generating an alternate prologue and epilogue that realigns the run-time stack if necessary. This supports mixing legacy codes that run with a 4-byte aligned stack with modern codes that keep a 16-byte stack for SSE compatibility.

`stdcall`
: On x86-32 targets, the `stdcall` attribute causes the compiler to assume that the called function pops off the stack space used to pass arguments, unless it takes a variable number of arguments.

`no_callee_saved_registers`
: Use this attribute to indicate that the specified function has no callee-saved registers. That is, all registers, except for stack and frame pointers, can be used as scratch registers. For example, this attribute can be used for a function called from the interrupt handler assembly stub which will preserve all registers and return from interrupt.

`preserve_none`
: This attribute is similar to `no_callee_saved_registers`, except on x86-64, r12, r13, r14, r15, rdi and rsi registers are used for integer parameter passing and this calling convention is subject to change.

`no_caller_saved_registers`
: Use this attribute to indicate that the specified function has no caller-saved registers. That is, all registers are callee-saved. For example, this attribute can be used for a function called from an interrupt handler. The compiler generates proper function entry and exit sequences to save and restore any modified registers, except for the EFLAGS register. Since GCC doesn't preserve YMM nor ZMM registers, `no_caller_saved_registers` attribute can't be used on functions with AVX enabled. Note that MMX and x87 registers aren't preserved by `no_caller_saved_registers` attribute.

`interrupt`

Use this attribute to indicate that the specified function is an interrupt handler or an exception handler (depending on parameters passed to the function, explained further). The compiler generates function entry and exit sequences suitable for use in an interrupt handler when this attribute is present. The `IRET` instruction, instead of the `RET` instruction, is used to return from interrupt handlers. All registers, except for the EFLAGS register which is restored by the `IRET` instruction, are preserved by the compiler. Since GCC doesn't preserve SSE, MMX nor x87 states, the GCC option `-mgeneral-regs-only` should be used to compile interrupt and exception handlers.

Any interruptible-without-stack-switch code must be compiled with `-mno-red-zone` since interrupt handlers can and will, because of the hardware design, touch the red zone.

An interrupt handler must be declared with a mandatory pointer argument:

```
struct interrupt_frame;

__attribute__ ((interrupt))
void
f (struct interrupt_frame *frame)
{
}
```

and you must define `struct interrupt_frame` as described in the processor's manual.

Exception handlers differ from interrupt handlers because the system pushes an error code on the stack. An exception handler declaration is similar to that for an interrupt handler, but with a different mandatory function signature. The compiler arranges to pop the error code off the stack before the `IRET` instruction.

```
#ifdef __x86_64__
typedef unsigned long long int uword_t;
#else
typedef unsigned int uword_t;
#endif

struct interrupt_frame;

__attribute__ ((interrupt))
void
f (struct interrupt_frame *frame, uword_t error_code)
{
  ...
}
```

Exception handlers should only be used for exceptions that push an error code; you should use an interrupt handler in other cases. The system will crash if the wrong kind of handler is used.

`target (`*`options`*`)`

As discussed in Section 6.4.1.1 [Common Function Attributes], page 622, this attribute allows specification of target-specific compilation options.

On the x86, the following options are allowed:

'3dnow'
'no-3dnow'
: Enable/disable the generation of the 3DNow! instructions.

'3dnowa'
'no-3dnowa'
: Enable/disable the generation of the enhanced 3DNow! instructions.

'abm'
'no-abm'
: Enable/disable the generation of the advanced bit instructions.

'adx'
'no-adx'
: Enable/disable the generation of the ADX instructions.

'aes'
'no-aes'
: Enable/disable the generation of the AES instructions.

'avx'
'no-avx'
: Enable/disable the generation of the AVX instructions.

'avx2'
'no-avx2'
: Enable/disable the generation of the AVX2 instructions.

'avx512bitalg'
'no-avx512bitalg'
: Enable/disable the generation of the AVX512BITALG instructions.

'avx512bw'
'no-avx512bw'
: Enable/disable the generation of the AVX512BW instructions.

'avx512cd'
'no-avx512cd'
: Enable/disable the generation of the AVX512CD instructions.

'avx512dq'
'no-avx512dq'
: Enable/disable the generation of the AVX512DQ instructions.

'avx512er'
'no-avx512er'
: Enable/disable the generation of the AVX512ER instructions.

'avx512f'
'no-avx512f'
: Enable/disable the generation of the AVX512F instructions.

'avx512ifma'
'no-avx512ifma'
: Enable/disable the generation of the AVX512IFMA instructions.

'avx512vbmi'
'no-avx512vbmi'
: Enable/disable the generation of the AVX512VBMI instructions.

'avx512vbmi2'
'no-avx512vbmi2'
Enable/disable the generation of the AVX512VBMI2 instructions.

'avx512vl'
'no-avx512vl'
Enable/disable the generation of the AVX512VL instructions.

'avx512vnni'
'no-avx512vnni'
Enable/disable the generation of the AVX512VNNI instructions.

'avx512vpopcntdq'
'no-avx512vpopcntdq'
Enable/disable the generation of the AVX512VPOPCNTDQ instructions.

'bmi'
'no-bmi' Enable/disable the generation of the BMI instructions.

'bmi2'
'no-bmi2' Enable/disable the generation of the BMI2 instructions.

'cldemote'
'no-cldemote'
Enable/disable the generation of the CLDEMOTE instructions.

'clflushopt'
'no-clflushopt'
Enable/disable the generation of the CLFLUSHOPT instructions.

'clwb'
'no-clwb' Enable/disable the generation of the CLWB instructions.

'clzero'
'no-clzero'
Enable/disable the generation of the CLZERO instructions.

'crc32'
'no-crc32'
Enable/disable the generation of the CRC32 instructions.

'cx16'
'no-cx16' Enable/disable the generation of the CMPXCHG16B instructions.

'default' See Section 8.8 [Function Multiversioning], page 1069, where it is used to specify the default function version.

'f16c'
'no-f16c' Enable/disable the generation of the F16C instructions.

'fma'
'no-fma' Enable/disable the generation of the FMA instructions.

'fma4'
'no-fma4' Enable/disable the generation of the FMA4 instructions.

'fsgsbase'
'no-fsgsbase'
Enable/disable the generation of the FSGSBASE instructions.

'fxsr'
'no-fxsr' Enable/disable the generation of the FXSR instructions.

'gfni'
'no-gfni' Enable/disable the generation of the GFNI instructions.

'hle'
'no-hle' Enable/disable the generation of the HLE instruction prefixes.

'lwp'
'no-lwp' Enable/disable the generation of the LWP instructions.

'lzcnt'
'no-lzcnt'
Enable/disable the generation of the LZCNT instructions.

'mmx'
'no-mmx' Enable/disable the generation of the MMX instructions.

'movbe'
'no-movbe'
Enable/disable the generation of the MOVBE instructions.

'movdir64b'
'no-movdir64b'
Enable/disable the generation of the MOVDIR64B instructions.

'movdiri'
'no-movdiri'
Enable/disable the generation of the MOVDIRI instructions.

'mwait'
'no-mwait'
Enable/disable the generation of the MWAIT and MONITOR instructions.

'mwaitx'
'no-mwaitx'
Enable/disable the generation of the MWAITX instructions.

'pclmul'
'no-pclmul'
Enable/disable the generation of the PCLMUL instructions.

'pconfig'
'no-pconfig'
Enable/disable the generation of the PCONFIG instructions.

'pku'
'no-pku' Enable/disable the generation of the PKU instructions.

'popcnt'
'no-popcnt'
Enable/disable the generation of the POPCNT instruction.

'prfchw'
'no-prfchw'
Enable/disable the generation of the PREFETCHW instruction.

'ptwrite'
'no-ptwrite'
Enable/disable the generation of the PTWRITE instructions.

'rdpid'
'no-rdpid'
Enable/disable the generation of the RDPID instructions.

'rdrnd'
'no-rdrnd'
Enable/disable the generation of the RDRND instructions.

'rdseed'
'no-rdseed'
Enable/disable the generation of the RDSEED instructions.

'rtm'
'no-rtm' Enable/disable the generation of the RTM instructions.

'sahf'
'no-sahf' Enable/disable the generation of the SAHF instructions.

'sgx'
'no-sgx' Enable/disable the generation of the SGX instructions.

'sha'
'no-sha' Enable/disable the generation of the SHA instructions.

'shstk'
'no-shstk'
Enable/disable the shadow stack built-in functions from CET.

'sse'
'no-sse' Enable/disable the generation of the SSE instructions.

'sse2'
'no-sse2' Enable/disable the generation of the SSE2 instructions.

'sse3'
'no-sse3' Enable/disable the generation of the SSE3 instructions.

'sse4'
'no-sse4' Enable/disable the generation of the SSE4 instructions (both SSE4.1 and SSE4.2).

'sse4.1'
'no-sse4.1'
Enable/disable the generation of the SSE4.1 instructions.

'sse4.2'
'no-sse4.2'
Enable/disable the generation of the SSE4.2 instructions.

'sse4a'
'no-sse4a'
Enable/disable the generation of the SSE4A instructions.

'ssse3'
'no-ssse3'
Enable/disable the generation of the SSSE3 instructions.

'tbm'
'no-tbm' Enable/disable the generation of the TBM instructions.

'vaes'
'no-vaes' Enable/disable the generation of the VAES instructions.

'vpclmulqdq'
'no-vpclmulqdq'
Enable/disable the generation of the VPCLMULQDQ instructions.

'waitpkg'
'no-waitpkg'
Enable/disable the generation of the WAITPKG instructions.

'wbnoinvd'
'no-wbnoinvd'
Enable/disable the generation of the WBNOINVD instructions.

'xop'
'no-xop' Enable/disable the generation of the XOP instructions.

'xsave'
'no-xsave'
Enable/disable the generation of the XSAVE instructions.

'xsavec'
'no-xsavec'
Enable/disable the generation of the XSAVEC instructions.

'xsaveopt'
'no-xsaveopt'
Enable/disable the generation of the XSAVEOPT instructions.

'xsaves'
'no-xsaves'
Enable/disable the generation of the XSAVES instructions.

'amx-tile'
'no-amx-tile'
Enable/disable the generation of the AMX-TILE instructions.

'amx-int8'
'no-amx-int8'
Enable/disable the generation of the AMX-INT8 instructions.

'amx-bf16'
'no-amx-bf16'
Enable/disable the generation of the AMX-BF16 instructions.

'uintr'
'no-uintr'
Enable/disable the generation of the UINTR instructions.

'hreset'
'no-hreset'
Enable/disable the generation of the HRESET instruction.

'kl'
'no-kl' Enable/disable the generation of the KEYLOCKER instructions.

'widekl'
'no-widekl'
Enable/disable the generation of the WIDEKL instructions.

'avxvnni'
'no-avxvnni'
Enable/disable the generation of the AVXVNNI instructions.

'avxifma'
'no-avxifma'
Enable/disable the generation of the AVXIFMA instructions.

'avxvnniint8'
'no-avxvnniint8'
Enable/disable the generation of the AVXVNNIINT8 instructions.

'avxneconvert'
'no-avxneconvert'
Enable/disable the generation of the AVXNECONVERT instructions.

'cmpccxadd'
'no-cmpccxadd'
Enable/disable the generation of the CMPccXADD instructions.

'amx-fp16'
'no-amx-fp16'
Enable/disable the generation of the AMX-FP16 instructions.

'prefetchi'
'no-prefetchi'
Enable/disable the generation of the PREFETCHI instructions.

'raoint'
'no-raoint'
Enable/disable the generation of the RAOINT instructions.

'amx-complex'
'no-amx-complex'
Enable/disable the generation of the AMX-COMPLEX instructions.

'avxvnniint16'
'no-avxvnniint16'
Enable/disable the generation of the AVXVNNIINT16 instructions.

'sm3'
'no-sm3' Enable/disable the generation of the SM3 instructions.

'sha512'
'no-sha512'
Enable/disable the generation of the SHA512 instructions.

'sm4'
'no-sm4' Enable/disable the generation of the SM4 instructions.

'usermsr'
'no-usermsr'
Enable/disable the generation of the USER_MSR instructions.

'apxf'
'no-apxf' Enable/disable the generation of the APX features, including EGPR, PUSH2POP2, NDD and PPX.

'avx10.1'
'no-avx10.1'
Enable/Disable the generation of the AVX10.1 instructions.

'avx10.2'
'no-avx10.2'
Enable/Disable the generation of the AVX10.2 instructions.

'amx-avx512'
'no-amx-avx512'
Enable/disable the generation of the AMX-AVX512 instructions.

'amx-tf32'
'no-amx-tf32'
Enable/disable the generation of the AMX-TF32 instructions.

'amx-fp8'
'no-amx-fp8'
Enable/disable the generation of the AMX-FP8 instructions.

'movrs'
'no-movrs'
Enable/disable the generation of the MOVRS instructions.

'amx-movrs'
'no-amx-movrs'
Enable/disable the generation of the AMX-MOVRS instructions.

'cld'
'no-cld' Enable/disable the generation of the CLD before string moves.

'fancy-math-387'
'no-fancy-math-387'
: Enable/disable the generation of the `sin`, `cos`, and `sqrt` instructions on the 387 floating-point unit.

'ieee-fp'
'no-ieee-fp'
: Enable/disable the generation of floating point that depends on IEEE arithmetic.

'inline-all-stringops'
'no-inline-all-stringops'
: Enable/disable inlining of string operations.

'inline-stringops-dynamically'
'no-inline-stringops-dynamically'
: Enable/disable the generation of the inline code to do small string operations and calling the library routines for large operations.

'align-stringops'
'no-align-stringops'
: Do/do not align destination of inlined string operations.

'recip'
'no-recip'
: Enable/disable the generation of RCPSS, RCPPS, RSQRTSS and RSQRTPS instructions followed an additional Newton-Raphson step instead of doing a floating-point division.

'80387'
'no-80387'
: Generate code containing 80387 instructions for floating point.

'general-regs-only'
: Generate code which uses only the general registers.

'arch=*ARCH*'
: Specify the architecture to generate code for in compiling the function.

'tune=*TUNE*'
: Specify the architecture to tune for in compiling the function.

'fpmath=*FPMATH*'
: Specify which floating-point unit to use. You must specify the `target("fpmath=sse,387")` option as `target("fpmath=sse+387")` because the comma would separate different options.

'prefer-vector-width=*OPT*'
: On x86 targets, the `prefer-vector-width` attribute informs the compiler to use *OPT*-bit vector width in instructions instead of the default on the selected platform.

Valid *OPT* values are:

'none' No extra limitations applied to GCC other than defined by the selected platform.

'128' Prefer 128-bit vector width for instructions.

'256' Prefer 256-bit vector width for instructions.

'512' Prefer 512-bit vector width for instructions.

`indirect_branch("choice")`

On x86 targets, the `indirect_branch` attribute causes the compiler to convert indirect call and jump with *choice*. '`keep`' keeps indirect call and jump unmodified. '`thunk`' converts indirect call and jump to call and return thunk. '`thunk-inline`' converts indirect call and jump to inlined call and return thunk. '`thunk-extern`' converts indirect call and jump to external call and return thunk provided in a separate object file.

`function_return("choice")`

On x86 targets, the `function_return` attribute causes the compiler to convert function return with *choice*. '`keep`' keeps function return unmodified. '`thunk`' converts function return to call and return thunk. '`thunk-inline`' converts function return to inlined call and return thunk. '`thunk-extern`' converts function return to external call and return thunk provided in a separate object file.

`nocf_check`

The `nocf_check` attribute on a function is used to inform the compiler that the function's prologue should not be instrumented when compiled with the `-fcf-protection=branch` option. The compiler assumes that the function's address is a valid target for a control-flow transfer.

The `nocf_check` attribute on a type of pointer to function is used to inform the compiler that a call through the pointer should not be instrumented when compiled with the `-fcf-protection=branch` option. The compiler assumes that the function's address from the pointer is a valid target for a control-flow transfer. A direct function call through a function name is assumed to be a safe call thus direct calls are not instrumented by the compiler.

The `nocf_check` attribute is applied to an object's type. In case of assignment of a function address or a function pointer to another pointer, the attribute is not carried over from the right-hand object's type; the type of left-hand object stays unchanged. The compiler checks for `nocf_check` attribute mismatch and reports a warning in case of mismatch.

```
int foo (void) __attribute__((nocf_check));
void (*foo1)(void) __attribute__((nocf_check));
void (*foo2)(void);

/* foo's address is assumed to be valid.  */
int
foo (void)
{
  /* This call site is not checked for control-flow
     validity.  */
```

```
      (*foo1)();

      /* A warning is issued about attribute mismatch.  */
      foo1 = foo2;

      /* This call site is still not checked.  */
      (*foo1)();

      /* This call site is checked.  */
      (*foo2)();

      /* A warning is issued about attribute mismatch.  */
      foo2 = foo1;

      /* This call site is still checked.  */
      (*foo2)();

      return 0;
    }
```

`cf_check`
: The `cf_check` attribute on a function is used to inform the compiler that ENDBR instruction should be placed at the function entry when `-fcf-protection=branch` is enabled.

`indirect_return`
: The `indirect_return` attribute can be applied to a function, as well as variable or type of function pointer to inform the compiler that the function may return via indirect branch.

`fentry_name("`*`name`*`")`
: On x86 targets, the `fentry_name` attribute sets the function to call on function entry when function instrumentation is enabled with `-pg -mfentry`. When *name* is nop then a 5 byte nop sequence is generated.

`fentry_section("`*`name`*`")`
: On x86 targets, the `fentry_section` attribute sets the name of the section to record function entry instrumentation calls in when enabled with `-pg -mrecord-mcount`

`nodirect_extern_access`
: This attribute, attached to a global variable or function, is the counterpart to option `-mno-direct-extern-access`.

Inlining rules

On the x86, the inliner does not inline a function that has different target options than the caller, unless the callee has a subset of the target options of the caller. For example a function declared with `target("sse3")` can inline a function with `target("sse2")`, since `-msse3` implies `-msse2`.

Besides the basic rule, when a function specifies `target("arch=`*`ARCH`*`")` or `target("tune=`*`TUNE`*`")` attribute, the inlining rule will be different. It allows inlining of a function with default `-march=x86-64` and `-mtune=generic` specified, or a function that has a subset of ISA features and marked with always_inline.

6.4.1.34 Xstormy16 Function Attributes

These function attributes are supported by the Xstormy16 back end:

`interrupt`
: Use this attribute to indicate that the specified function is an interrupt handler. The compiler generates function entry and exit sequences suitable for use in an interrupt handler when this attribute is present.

6.4.2 Specifying Attributes of Variables

You can use attributes to specify special properties of variables, function parameters, or structure, union, and, in C++, class members. Some attributes are currently defined generically for variables. Other attributes are defined for variables on particular target systems. Other attributes are available for functions (see Section 6.4.1 [Function Attributes], page 621), labels (see Section 6.4.4 [Label Attributes], page 730), enumerators (see Section 6.4.5 [Enumerator Attributes], page 731), statements (see Section 6.4.6 [Statement Attributes], page 732), and for types (see Section 6.4.3 [Type Attributes], page 715). Other front ends might define more attributes (see Chapter 8 [Extensions to the C++ Language], page 1061).

GCC provides two different ways to specify attributes: the traditional GNU syntax using '`__attribute__ ((...))`' annotations, and the newer standard C and C++ syntax using '`[[...]]`' with the '`gnu::`' prefix on attribute names. Note that the exact rules for placement of attributes in your source code are different depending on which syntax you use. See Section 6.4.7 [Attribute Syntax], page 734, for details.

6.4.2.1 Common Variable Attributes

The following attributes are supported on most targets.

`alias ("target")`
: The `alias` variable attribute causes the declaration to be emitted as an alias for another symbol known as an *alias target*. Except for top-level qualifiers the alias target must have the same type as the alias. For instance, the following

```
int var_target;
extern int __attribute__ ((alias ("var_target"))) var_alias;
```

defines `var_alias` to be an alias for the `var_target` variable.

It is an error if the alias target is not defined in the same translation unit as the alias.

Note that in the absence of the attribute GCC assumes that distinct declarations with external linkage denote distinct objects. Using both the alias and the alias target to access the same object is undefined in a translation unit without a declaration of the alias with the attribute.

This attribute requires assembler and object file support, and may not be available on all targets.

`aligned`
`aligned (alignment)`
: The `aligned` attribute specifies a minimum alignment for the variable or structure field, measured in bytes. When specified, *alignment* must be an integer

constant power of 2. Specifying no *alignment* argument implies the maximum alignment for the target, which is often, but by no means always, 8 or 16 bytes.

For example, the declaration:

```
int x __attribute__ ((aligned (16))) = 0;
```

causes the compiler to allocate the global variable `x` on a 16-byte boundary. On a 68040, this could be used in conjunction with an `asm` expression to access the `move16` instruction which requires 16-byte aligned operands.

You can also specify the alignment of structure fields. For example, to create a double-word aligned `int` pair, you could write:

```
struct foo { int x[2] __attribute__ ((aligned (8))); };
```

This is an alternative to creating a union with a `double` member, which forces the union to be double-word aligned.

As in the preceding examples, you can explicitly specify the alignment (in bytes) that you wish the compiler to use for a given variable or structure field. Alternatively, you can leave out the alignment factor and just ask the compiler to align a variable or field to the default alignment for the target architecture you are compiling for. The default alignment is sufficient for all scalar types, but may not be enough for all vector types on a target that supports vector operations. The default alignment is fixed for a particular target ABI.

GCC also provides a target specific macro `__BIGGEST_ALIGNMENT__`, which is the largest alignment ever used for any data type on the target machine you are compiling for. For example, you could write:

```
short array[3] __attribute__ ((aligned (__BIGGEST_ALIGNMENT__)));
```

The compiler automatically sets the alignment for the declared variable or field to `__BIGGEST_ALIGNMENT__`. Doing this can often make copy operations more efficient, because the compiler can use whatever instructions copy the biggest chunks of memory when performing copies to or from the variables or fields that you have aligned this way. Note that the value of `__BIGGEST_ALIGNMENT__` may change depending on command-line options.

When used on a struct, or struct member, the `aligned` attribute can only increase the alignment; in order to decrease it, the `packed` attribute must be specified as well. When used as part of a typedef, the `aligned` attribute can both increase and decrease alignment, and specifying the `packed` attribute generates a warning.

Note that the effectiveness of `aligned` attributes for static variables may be limited by inherent limitations in the system linker and/or object file format. On some systems, the linker is only able to arrange for variables to be aligned up to a certain maximum alignment. (For some linkers, the maximum supported alignment may be very very small.) If your linker is only able to align variables up to a maximum of 8-byte alignment, then specifying `aligned(16)` in an `__attribute__` still only provides you with 8-byte alignment. See your linker documentation for further information.

Stack variables are not affected by linker restrictions; GCC can properly align them on any target.

The `aligned` attribute can also be used for functions (see Section 6.4.1.1 [Common Function Attributes], page 622.)

`alloc_size (`*`position`*`)`
`alloc_size (`*`position-1`*`, `*`position-2`*`)`

The `alloc_size` variable attribute may be applied to the declaration of a pointer to a function that returns a pointer and takes at least one argument of an integer type. It indicates that the returned pointer points to an object whose size is given by the function argument at *position*, or by the product of the arguments at *position-1* and *position-2*. Meaningful sizes are positive values less than `PTRDIFF_MAX`. Other sizes are diagnosed when detected. GCC uses this information to improve the results of `__builtin_object_size`.

For instance, the following declarations

```
typedef __attribute__ ((alloc_size (1, 2))) void*
  (*calloc_ptr) (size_t, size_t);
typedef __attribute__ ((alloc_size (1))) void*
  (*malloc_ptr) (size_t);
```

specify that `calloc_ptr` is a pointer of a function that, like the standard C function `calloc`, returns an object whose size is given by the product of arguments 1 and 2, and similarly, that `malloc_ptr`, like the standard C function `malloc`, returns an object whose size is given by argument 1 to the function.

`btf_decl_tag (`*`argument`*`)`

The `btf_decl_tag` attribute may be used to associate variable declarations, struct or union member declarations, function declarations, and function parameter declarations with arbitrary strings. These strings are not interpreted by the compiler in any way, and have no effect on code generation. Instead, these user-provided strings are recorded in DWARF (via `DW_AT_GNU_annotation` and `DW_TAG_GNU_annotation` extensions) and BTF information (via `BTF_KIND_DECL_TAG` records), and associated to the attributed declaration. If neither DWARF nor BTF information is generated, the attribute has no effect.

The argument is treated as a null-terminated sequence of zero or more non-null bytes. Wide character strings are not supported.

The attribute may be supplied multiple times for a single declaration, in which case each distinct argument string will be recorded in a separate DIE or BTF record, each associated to the declaration. For a single declaration with multiple `btf_decl_tag` attributes, the order of the `DW_TAG_GNU_annotation` DIEs produced is not guaranteed to maintain the order of attributes in the source code.

For example:

```
int *foo __attribute__ ((btf_decl_tag ("__percpu")));
```

when compiled with `-gbtf` results in an additional `BTF_KIND_DECL_TAG` BTF record to be emitted in the BTF info, associating the string '`__percpu`' with the `BTF_KIND_VAR` record for the variable `foo`.

`cleanup (`*`cleanup_function`*`)`

The `cleanup` attribute runs a function when the variable goes out of scope. This attribute can only be applied to auto function scope variables; it may not be applied to parameters or variables with static storage duration. The function must take one parameter, a pointer to a type compatible with the variable. The return value of the function (if any) is ignored.

When multiple variables in the same scope have `cleanup` attributes, at exit from the scope their associated cleanup functions are run in reverse order of definition (last defined, first cleanup).

If `-fexceptions` is enabled, then *cleanup_function* is run during the stack unwinding that happens during the processing of the exception. Note that the `cleanup` attribute does not allow the exception to be caught, only to perform an action. It is undefined what happens if *cleanup_function* does not return normally.

`common`
`nocommon` The `common` attribute requests GCC to place a variable in "common" storage. The `nocommon` attribute requests the opposite—to allocate space for it directly.

These attributes override the default chosen by the `-fno-common` and `-fcommon` flags respectively.

`copy`
`copy (`*`variable`*`)`

The `copy` attribute applies the set of attributes with which *variable* has been declared to the declaration of the variable to which the attribute is applied. The attribute is designed for libraries that define aliases that are expected to specify the same set of attributes as the aliased symbols. The `copy` attribute can be used with variables, functions or types. However, the kind of symbol to which the attribute is applied (either varible or function) must match the kind of symbol to which the argument refers. The `copy` attribute copies only syntactic and semantic attributes but not attributes that affect a symbol's linkage or visibility such as `alias`, `visibility`, or `weak`. The `deprecated` attribute is also not copied. See Section 6.4.1.1 [Common Function Attributes], page 622. See Section 6.4.3.1 [Common Type Attributes], page 715.

`counted_by (`*`count`*`)`

The `counted_by` attribute may be attached to the C99 flexible array member, or a pointer field of a structure. It indicates that the number of the elements of the array that is held by the flexible array member field, or is pointed to by the pointer field, is given by the field "*count*" in the same structure as the flexible array member or the pointer field.

This attribute is available only in C for now. In C++ this attribute is ignored.

GCC may use this information to improve detection of object size information for such structures and provide better results in compile-time diagnostics and runtime features like the array bound sanitizer and the `__builtin_dynamic_object_size`.

For instance, the following code:

```
struct P {
  size_t count;
  char other;
  char array[] __attribute__ ((counted_by (count)));
```

```
} *p;
```

specifies that the `array` is a flexible array member whose number of elements is given by the field `count` in the same structure.

```
struct PP {
  size_t count2;
  char other1;
  char *array2 __attribute__ ((counted_by (count2)));
  int other2;
} *pp;
```

specifies that the `array2` is an array that is pointed by the pointer field, and its number of elements is given by the field `count2` in the same structure.

The field that represents the number of the elements should have an integer type. Otherwise, the compiler reports an error and ignores the attribute.

When the field that represents the number of the elements is assigned a negative integer value, the compiler treats the value as zero.

The `counted_by` attribute is not allowed for a pointer to function, or a pointer to a structure or union that includes a flexible array member. However, it is allowed for a pointer to non-void incomplete structure or union types, as long as the type could be completed before the first reference to the pointer.

The attribute is allowed for a pointer to `void`. However, warnings will be issued for such cases when `-Wpointer-arith` is specified. When this attribute is applied on a pointer to `void`, the size of each element of this pointer array is treated as 1.

An explicit `counted_by` annotation defines a relationship between two objects, `p->array` and `p->count`, and there are the following requirements on the relationship between this pair:

- `p->count` must be initialized before the first reference to `p->array`;
- `p->array` has *at least* `p->count` number of elements available all the time. This relationship must hold even after any of these related objects are updated during the program.

In addition to the above requirements, there is one more requirement between this pair if and only if `p->array` is an array that is pointed by the pointer field:

`p->array` and `p->count` can only be changed by changing the whole structure at the same time.

It's the programmer's responsibility to make sure the above requirements to be kept all the time. Otherwise the compiler reports warnings and the results of the array bound sanitizer and the `__builtin_dynamic_object_size` built-in are undefined.

One important feature of the attribute is that a reference to the flexible array member field uses the latest value assigned to the field that represents the number of the elements before that reference. For example,

```
  p->count = val1;
  p->array[20] = 0;  // ref1 to p->array
  p->count = val2;
  p->array[30] = 0;  // ref2 to p->array
```

In the above, ref1 uses val1 as the number of the elements in p->array, and ref2 uses val2 as the number of elements in p->array.

Note, however, the above feature is not valid for the pointer field.

deprecated
deprecated (*msg*)

The deprecated attribute results in a warning if the variable is used anywhere in the source file. This is useful when identifying variables that are expected to be removed in a future version of a program. The warning also includes the location of the declaration of the deprecated variable, to enable users to easily find further information about why the variable is deprecated, or what they should do instead. Note that the warning only occurs for uses:

```
extern int old_var __attribute__ ((deprecated));
extern int old_var;
int new_fn () { return old_var; }
```

results in a warning on line 3 but not line 2. The optional *msg* argument, which must be a string, is printed in the warning if present.

The deprecated attribute can also be used for functions and types (see Section 6.4.1.1 [Common Function Attributes], page 622, see Section 6.4.3.1 [Common Type Attributes], page 715).

The message attached to the attribute is affected by the setting of the -fmessage-length option.

mode (*mode*)

This attribute specifies the data type for the declaration—whichever type corresponds to the mode *mode*. This in effect lets you request an integer or floating-point type according to its width.

See Section "Machine Modes" in *GNU Compiler Collection (GCC) Internals*, for a list of the possible keywords for *mode*. You may also specify a mode of byte or __byte__ to indicate the mode corresponding to a one-byte integer, word or __word__ for the mode of a one-word integer, and pointer or __pointer__ for the mode used to represent pointers.

no_icf

This variable attribute prevents a variable from being merged with another equivalent variable.

noinit

Any data with the noinit attribute will not be initialized by the C runtime startup code, or the program loader. Not initializing data in this way can reduce program startup times.

This attribute is specific to ELF targets and relies on the linker script to place sections with the .noinit prefix in the right location.

nonstring

The nonstring variable attribute specifies that an object or member declaration with type array of char, signed char, or unsigned char, or pointer to such a type is intended to store character arrays that do not necessarily contain a terminating NUL. This is useful in detecting uses of such arrays or pointers with functions that expect NUL-terminated strings, and to avoid warnings when such an array or pointer is used as an argument to a bounded string manipulation function such as `strncpy`. For example, without the attribute, GCC will issue a warning for the `strncpy` call below because it may truncate the copy without appending the terminating `NUL` character. Using the attribute makes it possible to suppress the warning. However, when the array is declared with the attribute the call to `strlen` is diagnosed because when the array doesn't contain a `NUL`-terminated string the call is undefined. To copy, compare, or search non-string character arrays use the `memcpy`, `memcmp`, `memchr`, and other functions that operate on arrays of bytes. In addition, calling `strnlen` and `strndup` with such arrays is safe provided a suitable bound is specified, and not diagnosed.

```
struct Data
{
  char name [32] __attribute__ ((nonstring));
};

int f (struct Data *pd, const char *s)
{
  strncpy (pd->name, s, sizeof pd->name);
  ...
  return strlen (pd->name);   // unsafe, gets a warning
}
```

`objc_nullability (`*`nullability kind`*`)` (Objective-C and Objective-C++ only)

This attribute applies to pointer variables only. It allows marking the pointer with one of four possible values describing the conditions under which the pointer might have a `nil` value. In most cases, the attribute is intended to be an internal representation for property and method nullability (specified by language keywords); it is not recommended to use it directly.

When *nullability kind* is `"unspecified"` or `0`, nothing is known about the conditions in which the pointer might be `nil`. Making this state specific serves to avoid false positives in diagnostics.

When *nullability kind* is `"nonnull"` or `1`, the pointer has no meaning if it is `nil` and thus the compiler is free to emit diagnostics if it can be determined that the value will be `nil`.

When *nullability kind* is `"nullable"` or `2`, the pointer might be `nil` and carry meaning as such.

When *nullability kind* is `"resettable"` or `3` (used only in the context of property attribute lists) this describes the case in which a property setter may take the value `nil` (which perhaps causes the property to be reset in some manner to a default) but for which the property getter will never validly return `nil`.

`packed` The `packed` attribute specifies that a structure member should have the smallest possible alignment—one bit for a bit-field and one byte otherwise, unless a larger value is specified with the `aligned` attribute. The attribute does not apply to non-member objects.

For example in the structure below, the member array `x` is packed so that it immediately follows `a` with no intervening padding:

```
struct foo
```

```
{
  char a;
  int x[2] __attribute__ ((packed));
};
```

Note: The 4.1, 4.2 and 4.3 series of GCC ignore the `packed` attribute on bit-fields of type `char`. This has been fixed in GCC 4.4 but the change can lead to differences in the structure layout. See the documentation of `-Wpacked-bitfield-compat` for more information.

`persistent`

Any data with the `persistent` attribute will not be initialized by the C runtime startup code, but will be initialized by the program loader. This enables the value of the variable to '`persist`' between processor resets.

This attribute is specific to ELF targets and relies on the linker script to place the sections with the `.persistent` prefix in the right location. Specifically, some type of non-volatile, writable memory is required.

`section ("`*section-name*`")`

Normally, the compiler places the objects it generates in sections like `data` and `bss`. Sometimes, however, you need additional sections, or you need certain particular variables to appear in special sections, for example to map to special hardware. The `section` attribute specifies that a variable (or function) lives in a particular section. For example, this small program uses several specific section names:

```
struct duart a __attribute__ ((section ("DUART_A"))) = { 0 };
struct duart b __attribute__ ((section ("DUART_B"))) = { 0 };
char stack[10000] __attribute__ ((section ("STACK"))) = { 0 };
int init_data __attribute__ ((section ("INITDATA")));

main()
{
  /* Initialize stack pointer */
  init_sp (stack + sizeof (stack));

  /* Initialize initialized data */
  memcpy (&init_data, &data, &edata - &data);

  /* Turn on the serial ports */
  init_duart (&a);
  init_duart (&b);
}
```

Use the `section` attribute with *global* variables and not *local* variables, as shown in the example.

You may use the `section` attribute with initialized or uninitialized global variables but the linker requires each object be defined once, with the exception that uninitialized variables tentatively go in the `common` (or `bss`) section and can be multiply "defined". Using the `section` attribute changes what section the variable goes into and may cause the linker to issue an error if an uninitialized variable has multiple definitions. You can force a variable to be initialized with the `-fno-common` flag or the `nocommon` attribute.

Some file formats do not support arbitrary sections so the `section` attribute is not available on all platforms. If you need to map the entire contents of a module to a particular section, consider using the facilities of the linker instead.

`strict_flex_array (`*`level`*`)`

The `strict_flex_array` attribute should be attached to the trailing array field of a structure. It controls when to treat the trailing array field of a structure as a flexible array member for the purposes of accessing the elements of such an array. *level* must be an integer between 0 to 3.

level=0 is the least strict level, all trailing arrays of structures are treated as flexible array members. *level*=3 is the strictest level, only when the trailing array is declared as a flexible array member per C99 standard onwards (‘`[]`’), it is treated as a flexible array member.

There are two more levels in between 0 and 3, which are provided to support older code that uses the GCC zero-length array extension (‘`[0]`’) or one-element array as flexible array members (‘`[1]`’). When *level* is 1, the trailing array is treated as a flexible array member when it is declared as either ‘`[]`’, ‘`[0]`’, or ‘`[1]`’. When *level* is 2, the trailing array is treated as a flexible array member when it is declared as either ‘`[]`’, or ‘`[0]`’.

This attribute can be used with or without the `-fstrict-flex-arrays` command-line option. When both the attribute and the option are present at the same time, the level of the strictness for the specific trailing array field is determined by the attribute.

The `strict_flex_array` attribute interacts with the `-Wstrict-flex-arrays` option. See Section 3.9 [Warning Options], page 100, for more information.

`tls_model ("`*`tls_model`*`")`

The `tls_model` attribute sets thread-local storage model (see Section 6.6 [Thread-Local], page 746) of a particular `__thread` variable, overriding `-ftls-model=` command-line switch on a per-variable basis. The *tls_model* argument should be one of `global-dynamic`, `local-dynamic`, `initial-exec` or `local-exec`.

Not all targets support this attribute.

`unavailable`
`unavailable (`*`msg`*`)`

The `unavailable` attribute indicates that the variable so marked is not available, if it is used anywhere in the source file. It behaves in the same manner as the `deprecated` attribute except that the compiler will emit an error rather than a warning.

It is expected that items marked as `deprecated` will eventually be withdrawn from interfaces, and then become unavailable. This attribute allows for marking them appropriately.

The `unavailable` attribute can also be used for functions and types (see Section 6.4.1.1 [Common Function Attributes], page 622, see Section 6.4.3.1 [Common Type Attributes], page 715).

`unused` This attribute, attached to a variable or structure field, means that the variable or field is meant to be possibly unused. GCC does not produce a warning for this variable or field.

`used` This attribute, attached to a variable with static storage, means that the variable must be emitted even if it appears that the variable is not referenced.

When applied to a static data member of a C++ class template, the attribute also means that the member is instantiated if the class itself is instantiated.

`retain` For ELF targets that support the GNU or FreeBSD OSABIs, this attribute will save the variable from linker garbage collection. To support this behavior, variables that have not been placed in specific sections (e.g. by the `section` attribute, or the `-fdata-sections` option), will be placed in new, unique sections.

This additional functionality requires Binutils version 2.36 or later.

`uninitialized`

This attribute, attached to a variable with automatic storage, means that the variable should not be automatically initialized by the compiler when the option `-ftrivial-auto-var-init` presents.

With the option `-ftrivial-auto-var-init`, all the automatic variables that do not have explicit initializers will be initialized by the compiler. These additional compiler initializations might incur run-time overhead, sometimes dramatically. This attribute can be used to mark some variables to be excluded from such automatic initialization in order to reduce runtime overhead.

This attribute has no effect when the option `-ftrivial-auto-var-init` is not present.

`vector_size (`*`bytes`*`)`

This attribute specifies the vector size for the type of the declared variable, measured in bytes. The type to which it applies is known as the *base type*. The *bytes* argument must be a positive power-of-two multiple of the base type size. For example, the declaration:

```
int foo __attribute__ ((vector_size (16)));
```

causes the compiler to set the mode for `foo`, to be 16 bytes, divided into `int` sized units. Assuming a 32-bit `int`, `foo`'s type is a vector of four units of four bytes each, and the corresponding mode of `foo` is `V4SI`. See Section 7.8 [Vector Extensions], page 850, for details of manipulating vector variables.

This attribute is only applicable to integral and floating scalars, although arrays, pointers, and function return values are allowed in conjunction with this construct.

Aggregates with this attribute are invalid, even if they are of the same size as a corresponding scalar. For example, the declaration:

```
struct S { int a; };
struct S  __attribute__ ((vector_size (16))) foo;
```

is invalid even if the size of the structure is the same as the size of the `int`.

`visibility ("visibility_type")`
: This attribute affects the linkage of the declaration to which it is attached. The `visibility` attribute is described in Section 6.4.1.1 [Common Function Attributes], page 622.

`warn_if_not_aligned (alignment)`
: This attribute specifies a threshold for the structure field, measured in bytes. If the structure field is aligned below the threshold, a warning will be issued. For example, the declaration:

```
struct foo
{
  int i1;
  int i2;
  unsigned long long x __attribute__ ((warn_if_not_aligned (16)));
};
```

causes the compiler to issue an warning on `struct foo`, like '`warning: alignment 8 of 'struct foo' is less than 16`'. The compiler also issues a warning, like '`warning: 'x' offset 8 in 'struct foo' isn't aligned to 16`', when the structure field has the misaligned offset:

```
struct __attribute__ ((aligned (16))) foo
{
  int i1;
  int i2;
  unsigned long long x __attribute__ ((warn_if_not_aligned (16)));
};
```

This warning can be disabled by `-Wno-if-not-aligned`. The `warn_if_not_aligned` attribute can also be used for types (see Section 6.4.3.1 [Common Type Attributes], page 715.)

`weak`
: The `weak` attribute is described in Section 6.4.1.1 [Common Function Attributes], page 622.

6.4.2.2 ARC Variable Attributes

`aux`
: The `aux` attribute is used to directly access the ARC's auxiliary register space from C. The auxiliary register number is given via attribute argument.

6.4.2.3 AVR Variable Attributes

`progmem`
: The `progmem` attribute is used on the AVR to place read-only data in the non-volatile program memory (flash). The `progmem` attribute accomplishes this by putting respective variables into a section whose name starts with `.progmem`.

This attribute works similar to the `section` attribute but adds additional checking.

- Ordinary AVR cores with 32 general purpose registers:
  `progmem` affects the location of the data but not how this data is accessed. In order to read data located with the `progmem` attribute (inline) assembler must be used.

```
/* Use custom macros from AVR-LibC */
#include <avr/pgmspace.h>
```

```
/* Locate var in flash memory */
const int var[2] PROGMEM = { 1, 2 };

int read_var (int i)
{
    /* Access var[] by accessor macro from avr/pgmspace.h */
    return (int) pgm_read_word (& var[i]);
}
```

AVR is a Harvard architecture processor and data and read-only data normally resides in the data memory (RAM).

See also the [AVR Named Address Spaces], page 617, section for an alternate way to locate and access data in flash memory.

- AVR cores with flash memory visible in the RAM address range:

  On such devices, there is no need for attribute `progmem` or [`__flash`], page 617, qualifier at all. Just use standard C / C++. The compiler will generate `LD*` instructions. As flash memory is visible in the RAM address range, and the default linker script does *not* locate `.rodata` in RAM, no special features are needed in order not to waste RAM for read-only data or to read from flash. You might even get slightly better performance by avoiding `progmem` and `__flash`. This applies to devices from families `avrtiny` and `avrxmega3`, see Section 3.20.6 [AVR Options], page 388, for an overview.

- Reduced AVR Tiny cores like ATtiny40:

  The compiler adds `0x4000` to the addresses of objects and declarations in `progmem` and locates the objects in flash memory, namely in section `.progmem.data`. The offset is needed because the flash memory is visible in the RAM address space starting at address `0x4000`.

  Data in `progmem` can be accessed by means of ordinary C code, no special functions or macros are needed.

```
/* var is located in flash memory */
extern const int var[2] __attribute__((progmem));

int read_var (int i)
{
    return var[i];
}
```

  Please notice that on these devices, there is no need for `progmem` at all.

`io`
`io (`*`addr`*`)` Variables with the `io` attribute are used to address memory-mapped peripherals in the I/O address range. No memory is allocated. If an address is specified, the variable is assigned that address, and the value is interpreted as an address in the data address space. Example:

```
volatile int porta __attribute__((io (__AVR_SFR_OFFSET__ + 0x2)));
```

Otherwise, the variable is not assigned an address, but the compiler will still use `in` and `out` instructions where applicable, assuming some other module assigns an address in the I/O address range. Example:

```
extern volatile int porta __attribute__((io));
```

`io_low`
`io_low (addr)`
This is like the `io` attribute, but additionally it informs the compiler that the object lies in the lower half of the I/O area, allowing the use of `cbi`, `sbi`, `sbic` and `sbis` instructions.

`address (addr)`
Variables with the `address` attribute can be used to address memory-mapped peripherals that may lie outside the I/O address range. Just like with the `io` and `io_low` attributes, no memory is allocated.

```
volatile int porta __attribute__((address (0x600)));
```

This attribute can also be used to define symbols in C/C++ code which otherwise would require assembly, a linker description file or command-line options like `-Wl,--defsym,a_symbol=value`. For example,

```
int a_symbol __attribute__((weak, address (1234)));
```

will be compiled to

```
.weak a_symbol
a_symbol = 1234
```

`absdata` Variables in static storage and with the `absdata` attribute can be accessed by the `LDS` and `STS` instructions which take absolute addresses.

- This attribute is only supported for the reduced AVR Tiny core like ATtiny40.
- You must make sure that respective data is located in the address range `0x40...0xbf` accessible by `LDS` and `STS`. One way to achieve this as an appropriate linker description file.
- If the location does not fit the address range of `LDS` and `STS`, there is currently (Binutils 2.26) just an unspecific warning like

  ```
  module.cc:(.text+0x1c): warning: internal error: out
  of range error
  ```

See also the `-mabsdata` Section 3.20.6 [AVR Options], page 388.

6.4.2.4 Blackfin Variable Attributes

Three attributes are currently defined for the Blackfin.

`l1_data`
`l1_data_A`
`l1_data_B`
Use these attributes on the Blackfin to place the variable into L1 Data SRAM. Variables with `l1_data` attribute are put into the specific section named `.l1.data`. Those with `l1_data_A` attribute are put into the specific section named `.l1.data.A`. Those with `l1_data_B` attribute are put into the specific section named `.l1.data.B`.

`l2` Use this attribute on the Blackfin to place the variable into L2 SRAM. Variables with `l2` attribute are put into the specific section named `.l2.data`.

6.4.2.5 H8/300 Variable Attributes

These variable attributes are available for H8/300 targets:

`eightbit_data`
: Use this attribute on the H8/300, H8/300H, and H8S to indicate that the specified variable should be placed into the eight-bit data section. The compiler generates more efficient code for certain operations on data in the eight-bit data area. Note the eight-bit data area is limited to 256 bytes of data.

`tiny_data`
: Use this attribute on the H8/300H and H8S to indicate that the specified variable should be placed into the tiny data section. The compiler generates more efficient code for loads and stores on data in the tiny data section. Note the tiny data area is limited to slightly under 32KB of data.

6.4.2.6 IA-64 Variable Attributes

The IA-64 back end supports the following variable attribute:

`model (`*`model-name`*`)`
: On IA-64, use this attribute to set the addressability of an object. At present, the only supported identifier for *model-name* is `small`, indicating addressability via “small” (22-bit) addresses (so that their addresses can be loaded with the `addl` instruction). Caveat: such addressing is by definition not position independent and hence this attribute must not be used for objects defined by shared libraries.

6.4.2.7 LoongArch Variable Attributes

One attribute is currently defined for the LoongArch.

`model("`*`name`*`")`
: Use this attribute on the LoongArch to use a different code model for addressing this variable, than the code model specified by the global `-mcmodel` option. This attribute is mostly useful if a `section` attribute and/or a linker script will locate this object specially. Currently the only supported values of *name* are `normal` and `extreme`.

6.4.2.8 M32R/D Variable Attributes

One attribute is currently defined for the M32R/D.

`model (`*`model-name`*`)`
: Use this attribute on the M32R/D to set the addressability of an object. The identifier *model-name* is one of `small`, `medium`, or `large`, representing each of the code models.

  Small model objects live in the lower 16MB of memory (so that their addresses can be loaded with the `ld24` instruction).

Medium and large model objects may live anywhere in the 32-bit address space (the compiler generates `seth/add3` instructions to load their addresses).

6.4.2.9 Microsoft Windows Variable Attributes

You can use these attributes on Microsoft Windows targets. Section 6.4.2.15 [x86 Variable Attributes], page 714, for additional Windows compatibility attributes available on all x86 targets.

`dllimport`
`dllexport`
: The `dllimport` and `dllexport` attributes are described in Section 6.4.1.19 [Microsoft Windows Function Attributes], page 671.

`selectany`
: The `selectany` attribute causes an initialized global variable to have link-once semantics. When multiple definitions of the variable are encountered by the linker, the first is selected and the remainder are discarded. Following usage by the Microsoft compiler, the linker is told *not* to warn about size or content differences of the multiple definitions.

  Although the primary usage of this attribute is for POD types, the attribute can also be applied to global C++ objects that are initialized by a constructor. In this case, the static initialization and destruction code for the object is emitted in each translation defining the object, but the calls to the constructor and destructor are protected by a link-once guard variable.

  The `selectany` attribute is only available on Microsoft Windows targets. You can use `__declspec (selectany)` as a synonym for `__attribute__ ((selectany))` for compatibility with other compilers.

`shared`
: On Microsoft Windows, in addition to putting variable definitions in a named section, the section can also be shared among all running copies of an executable or DLL. For example, this small program defines shared data by putting it in a named section `shared` and marking the section shareable:

```
int foo __attribute__((section ("shared"), shared)) = 0;

int
main()
{
  /* Read and write foo.  All running
     copies see the same value.  */
  return 0;
}
```

  You may only use the `shared` attribute along with `section` attribute with a fully-initialized global definition because of the way linkers work. See `section` attribute for more information.

  The `shared` attribute is only available on Microsoft Windows.

6.4.2.10 MSP430 Variable Attributes

`upper`
`either`
: These attributes are the same as the MSP430 function attributes of the same name (see Section 6.4.1.21 [MSP430 Function Attributes], page 675).

`lower` This option behaves mostly the same as the MSP430 function attribute of the same name (see Section 6.4.1.21 [MSP430 Function Attributes], page 675), but it has some additional functionality.

If `-mdata-region={upper,either,none}` has been passed, or the `section` attribute is applied to a variable, the compiler will generate 430X instructions to handle it. This is because the compiler has to assume that the variable could get placed in the upper memory region (above address 0xFFFF). Marking the variable with the `lower` attribute informs the compiler that the variable will be placed in lower memory so it is safe to use 430 instructions to handle it.

In the case of the `section` attribute, the section name given will be used, and the `.lower` prefix will not be added.

6.4.2.11 Nvidia PTX Variable Attributes

These variable attributes are supported by the Nvidia PTX back end:

`shared` Use this attribute to place a variable in the `.shared` memory space. This memory space is private to each cooperative thread array; only threads within one thread block refer to the same instance of the variable. The runtime does not initialize variables in this memory space.

6.4.2.12 PowerPC Variable Attributes

Three attributes currently are defined for PowerPC configurations: `altivec`, `ms_struct` and `gcc_struct`.

For full documentation of the struct attributes please see the documentation in Section 6.4.2.15 [x86 Variable Attributes], page 714.

For documentation of `altivec` attribute please see the documentation in Section 6.4.3.5 [PowerPC Type Attributes], page 730.

6.4.2.13 RL78 Variable Attributes

The RL78 back end supports the `saddr` variable attribute. This specifies placement of the corresponding variable in the SADDR area, which can be accessed more efficiently than the default memory region.

6.4.2.14 V850 Variable Attributes

These variable attributes are supported by the V850 back end:

`sda` Use this attribute to explicitly place a variable in the small data area, which can hold up to 64 kilobytes.

`tda` Use this attribute to explicitly place a variable in the tiny data area, which can hold up to 256 bytes in total.

`zda` Use this attribute to explicitly place a variable in the first 32 kilobytes of memory.

6.4.2.15 x86 Variable Attributes

Two attributes are currently defined for x86 configurations: `ms_struct` and `gcc_struct`.

`ms_struct`
`gcc_struct`

If `packed` is used on a structure, or if bit-fields are used, it may be that the Microsoft ABI lays out the structure differently than the way GCC normally does. Particularly when moving packed data between functions compiled with GCC and the native Microsoft compiler (either via function call or as data in a file), it may be necessary to access either format.

The `ms_struct` and `gcc_struct` attributes correspond to the `-mms-bitfields` and `-mno-ms-bitfields` command-line options, respectively; see Section 3.20.54 [x86 Options], page 534, for details of how structure layout is affected. See Section 6.4.3.6 [x86 Type Attributes], page 730, for information about the corresponding attributes on types.

6.4.2.16 Xstormy16 Variable Attributes

One attribute is currently defined for xstormy16 configurations: `below100`.

`below100`

If a variable has the `below100` attribute (`BELOW100` is allowed also), GCC places the variable in the first 0x100 bytes of memory and use special opcodes to access it. Such variables are placed in either the `.bss_below100` section or the `.data_below100` section.

6.4.3 Specifying Attributes of Types

You can use attributes to specify various special properties of types. Some type attributes apply only to structure and union types, and in C++, also class types, while others can apply to any type defined via a `typedef` declaration. Unless otherwise specified, the same restrictions and effects apply to attributes regardless of whether a type is a trivial structure or a C++ class with user-defined constructors, destructors, or a copy assignment.

Other attributes are defined for functions (see Section 6.4.1 [Function Attributes], page 621), labels (see Section 6.4.4 [Label Attributes], page 730), enumerators (see Section 6.4.5 [Enumerator Attributes], page 731), statements (see Section 6.4.6 [Statement Attributes], page 732), and for variables (see Section 6.4.2 [Variable Attributes], page 699).

GCC provides two different ways to specify attributes: the traditional GNU syntax using '`__attribute__ ((...))`' annotations, and the newer standard C and C++ syntax using '`[[...]]`' with the '`gnu::`' prefix on attribute names. Note that the exact rules for placement of attributes in your source code are different depending on which syntax you use. See Section 6.4.7 [Attribute Syntax], page 734, for details.

You may specify type attributes in an enum, struct or union type declaration or definition by placing them immediately after the `struct`, `union` or `enum` keyword. You can also place them just past the closing curly brace of the definition, but this is less preferred because logically the type should be fully defined at the closing brace. You can also include type attributes in a `typedef` declaration.

6.4.3.1 Common Type Attributes

The following type attributes are supported on most targets.

`aligned`
`aligned (alignment)`

The `aligned` attribute specifies a minimum alignment (in bytes) for variables of the specified type. When specified, *alignment* must be a power of 2. Specifying no *alignment* argument implies the maximum alignment for the target, which is often, but by no means always, 8 or 16 bytes. For example, the declarations:

```
struct __attribute__ ((aligned (8))) S { short f[3]; };
typedef int more_aligned_int __attribute__ ((aligned (8)));
```

force the compiler to ensure (as far as it can) that each variable whose type is `struct S` or `more_aligned_int` is allocated and aligned *at least* on a 8-byte boundary. On a SPARC, having all variables of type `struct S` aligned to 8-byte boundaries allows the compiler to use the `ldd` and `std` (doubleword load and store) instructions when copying one variable of type `struct S` to another, thus improving run-time efficiency.

Note that the alignment of any given `struct` or `union` type is required by the ISO C standard to be at least a perfect multiple of the lowest common multiple of the alignments of all of the members of the `struct` or `union` in question. This means that you *can* effectively adjust the alignment of a `struct` or `union` type by attaching an `aligned` attribute to any one of the members of such a type, but the notation illustrated in the example above is a more obvious, intuitive, and readable way to request the compiler to adjust the alignment of an entire `struct` or `union` type.

As in the preceding example, you can explicitly specify the alignment (in bytes) that you wish the compiler to use for a given `struct` or `union` type. Alternatively, you can leave out the alignment factor and just ask the compiler to align a type to the maximum useful alignment for the target machine you are compiling for. For example, you could write:

```
struct __attribute__ ((aligned)) S { short f[3]; };
```

Whenever you leave out the alignment factor in an `aligned` attribute specification, the compiler automatically sets the alignment for the type to the largest alignment that is ever used for any data type on the target machine you are compiling for. Doing this can often make copy operations more efficient, because the compiler can use whatever instructions copy the biggest chunks of memory when performing copies to or from the variables that have types that you have aligned this way.

In the example above, if the size of each `short` is 2 bytes, then the size of the entire `struct S` type is 6 bytes. The smallest power of two that is greater than or equal to that is 8, so the compiler sets the alignment for the entire `struct S` type to 8 bytes.

Note that although you can ask the compiler to select a time-efficient alignment for a given type and then declare only individual stand-alone objects of that type, the compiler's ability to select a time-efficient alignment is primarily useful only when you plan to create arrays of variables having the relevant (efficiently aligned) type. If you declare or use arrays of variables of an efficiently-aligned type, then it is likely that your program also does pointer arithmetic (or subscripting, which amounts to the same thing) on pointers to the relevant type, and the code that the compiler generates for these pointer arithmetic operations is often more efficient for efficiently-aligned types than for other types.

Note that the effectiveness of `aligned` attributes may be limited by inherent limitations in your linker. On many systems, the linker is only able to arrange for variables to be aligned up to a certain maximum alignment. (For some linkers, the maximum supported alignment may be very very small.) If your linker is only able to align variables up to a maximum of 8-byte alignment, then specifying `aligned (16)` in an `__attribute__` still only provides you with 8-byte alignment. See your linker documentation for further information.

When used on a struct, or struct member, the `aligned` attribute can only increase the alignment; in order to decrease it, the `packed` attribute must be specified as well. When used as part of a typedef, the `aligned` attribute can both increase and decrease alignment, and specifying the `packed` attribute generates a warning.

`alloc_size (`*`position`*`)`
`alloc_size (`*`position-1`*`, `*`position-2`*`)`

The `alloc_size` type attribute may be applied to the definition of a type of a function that returns a pointer and takes at least one argument of an integer type. It indicates that the returned pointer points to an object whose size is given by the function argument at *position-1*, or by the product of the arguments at *position-1* and *position-2*. Meaningful sizes are positive values less than `PTRDIFF_MAX`. Other sizes are diagnosed when detected. GCC uses this information to improve the results of `__builtin_object_size`.

For instance, the following declarations

```
typedef __attribute__ ((alloc_size (1, 2))) void*
  calloc_type (size_t, size_t);
typedef __attribute__ ((alloc_size (1))) void*
  malloc_type (size_t);
```

specify that `calloc_type` is a type of a function that, like the standard C function `calloc`, returns an object whose size is given by the product of arguments 1 and 2, and that `malloc_type`, like the standard C function `malloc`, returns an object whose size is given by argument 1 to the function.

`btf_type_tag (`*`argument`*`)`

The `btf_type_tag` attribute may be used to associate (to "tag") particular types with arbitrary string annotations. These annotations are recorded in debugging info by supported debug formats, currently DWARF (via `DW_AT_GNU_annotation` and `DW_TAG_GNU_annotation` extensions) and BTF (via `BTF_KIND_TYPE_TAG` records). These annotation strings are not interpreted by the compiler in any way, and have no effect on code generation. If neither DWARF nor BTF information is generated, the attribute has no effect.

The argument is treated as a null-terminated sequence of zero or more non-null bytes. Wide character strings are not supported.

The attribute may be supplied multiple times for a single type, in which case each distinct argument string will be recorded in a separate DIE or BTF record, each associated to the type. For a single type with multiple `btf_type_tag` attributes, the order of the DW_TAG_GNU_annotation DIEs produced is not guaranteed to maintain the order of attributes in the source code.

For example the following code:

```
int * __attribute__ ((btf_type_tag ("__user"))) foo;
```

when compiled with -gbtf results in an additional BTF_KIND_TYPE_TAG BTF record to be emitted in the BTF info, associating the string '__user' with the normal BTF_KIND_PTR record for the pointer-to-integer type used in the declaration.

Note that the BTF format currently only has a representation for type tags associated with pointer types. Type tags on non-pointer types may be silently skipped when generating BTF.

copy
copy (*expression*)

The copy attribute applies the set of attributes with which the type of the *expression* has been declared to the declaration of the type to which the attribute is applied. The attribute is designed for libraries that define aliases that are expected to specify the same set of attributes as the aliased symbols. The copy attribute can be used with types, variables, or functions. However, the kind of symbol to which the attribute is applied (either varible or function) must match the kind of symbol to which the argument refers. The copy attribute copies only syntactic and semantic attributes but not attributes that affect a symbol's linkage or visibility such as alias, visibility, or weak. The deprecated attribute is also not copied. See Section 6.4.1.1 [Common Function Attributes], page 622. See Section 6.4.2.1 [Common Variable Attributes], page 699.

For example, suppose struct A below is defined in some third party library header to have the alignment requirement N and to force a warning whenever a variable of the type is not so aligned due to attribute packed. Specifying the copy attribute on the definition on the unrelated struct B has the effect of copying all relevant attributes from the type referenced by the pointer expression to struct B.

```
struct __attribute__ ((aligned (N), warn_if_not_aligned (N)))
A { /* ... */ };
struct __attribute__ ((copy ( (struct A *)0)) B { /* ... */ };
```

deprecated
deprecated (*msg*)

The deprecated attribute results in a warning if the type is used anywhere in the source file. This is useful when identifying types that are expected to be removed in a future version of a program. If possible, the warning also includes the location of the declaration of the deprecated type, to enable users to easily find further information about why the type is deprecated, or what they should do instead. Note that the warnings only occur for uses and then only if the type is being applied to an identifier that itself is not being declared as deprecated.

```
typedef int T1 __attribute__ ((deprecated));
T1 x;
typedef T1 T2;
T2 y;
```

```
typedef T1 T3 __attribute__ ((deprecated));
T3 z __attribute__ ((deprecated));
```

results in a warning on line 2 and 3 but not lines 4, 5, or 6. No warning is issued for line 4 because T2 is not explicitly deprecated. Line 5 has no warning because T3 is explicitly deprecated. Similarly for line 6. The optional *msg* argument, which must be a string, is printed in the warning if present. Control characters in the string will be replaced with escape sequences, and if the `-fmessage-length` option is set to 0 (its default value) then any newline characters will be ignored.

The `deprecated` attribute can also be used for functions and variables (see Section 6.4.1 [Function Attributes], page 621, see Section 6.4.2 [Variable Attributes], page 699.)

The message attached to the attribute is affected by the setting of the `-fmessage-length` option.

`designated_init`

This attribute may only be applied to structure types. It indicates that any initialization of an object of this type must use designated initializers rather than positional initializers. The intent of this attribute is to allow the programmer to indicate that a structure's layout may change, and that therefore relying on positional initialization will result in future breakage.

GCC emits warnings based on this attribute by default; use `-Wno-designated-init` to suppress them.

`flag_enum`

This attribute may be applied to an enumerated type to indicate that its enumerators are used in bitwise operations, so e.g. `-Wswitch` should not warn about a `case` that corresponds to a bitwise combination of enumerators.

`hardbool`
`hardbool (`*`false_value`*`)`
`hardbool (`*`false_value`*`, `*`true_value`*`)`

This attribute may only be applied to integral types in C, to introduce hardened boolean types. It turns the integral type into a boolean-like type with the same size and precision, that uses the specified values as representations for `false` and `true`. Underneath, it is actually an enumerated type, but its observable behavior is like that of `_Bool`, except for the strict internal representations, verified by runtime checks.

If *true_value* is omitted, the bitwise negation of *false_value* is used. If *false_value* is omitted, zero is used. The named representation values must be different when converted to the original integral type. Narrower bitfields are rejected if the representations become indistinguishable.

Values of such types automatically decay to `_Bool`, at which point, the selected representation values are mapped to the corresponding `_Bool` values. When the represented value is not determined, at compile time, to be either *false_value* or *true_value*, runtime verification calls `__builtin_trap` if it is neither. This is what makes them hardened boolean types.

When converting scalar types to such hardened boolean types, implicitly or explicitly, behavior corresponds to a conversion to `_Bool`, followed by a mapping from `false` and `true` to *false_value* and *true_value*, respectively.

```
typedef char __attribute__ ((__hardbool__ (0x5a))) hbool;
hbool first = 0;       /* False, stored as (char)0x5a.  */
hbool second = !first; /* True, stored as ~(char)0x5a.  */

static hbool zeroinit; /* False, stored as (char)0x5a.  */
auto hbool uninit;     /* Undefined, may trap.  */
```

When zero-initializing a variable or field of hardened boolean type (presumably held in static storage) the implied zero initializer gets converted to `_Bool`, and then to the hardened boolean type, so that the initial value is the hardened representation for `false`. Using that value is well defined. This is *not* the case when variables and fields of such types are uninitialized (presumably held in automatic or dynamic storage): their values are indeterminate, and using them invokes undefined behavior. Using them may trap or not, depending on the bits held in the storage (re)used for the variable, if any, and on optimizations the compiler may perform on the grounds that using uninitialized values invokes undefined behavior.

Users of `-ftrivial-auto-var-init` should be aware that the bit patterns used as initializers are *not* converted to `hardbool` types, so using a `hardbool` variable that is implicitly initialized by the `-ftrivial-auto-var-init` may trap if the representations values chosen for `false` and `true` do not match the initializer.

Since this is a language extension only available in C, interoperation with other languages may pose difficulties. It should interoperate with Ada Booleans defined with the same size and equivalent representation clauses, and with enumerations or other languages' integral types that correspond to C's chosen integral type.

`may_alias`

Accesses through pointers to types with this attribute are not subject to type-based alias analysis, but are instead assumed to be able to alias any other type of objects. In the context of section 6.5 paragraph 7 of the C99 standard, an lvalue expression dereferencing such a pointer is treated like having a character type. See `-fstrict-aliasing` for more information on aliasing issues. This extension exists to support some vector APIs, in which pointers to one vector type are permitted to alias pointers to a different vector type.

Note that an object of a type with this attribute does not have any special semantics.

Example of use:

```
typedef short __attribute__ ((__may_alias__)) short_a;

int
main (void)
{
  int a = 0x12345678;
  short_a *b = (short_a *) &a;

  b[1] = 0;
```

```
    if (a == 0x12345678)
      abort();

    exit(0);
  }
```

If you replaced `short_a` with `short` in the variable declaration, the above program would abort when compiled with `-fstrict-aliasing`, which is on by default at `-O2` or above.

`mode (`*mode*`)`
: This attribute specifies the data type for the declaration—whichever type corresponds to the mode *mode*. This in effect lets you request an integer or floating-point type according to its width.

  See Section "Machine Modes" in *GNU Compiler Collection (GCC) Internals*, for a list of the possible keywords for *mode*. You may also specify a mode of `byte` or `__byte__` to indicate the mode corresponding to a one-byte integer, `word` or `__word__` for the mode of a one-word integer, and `pointer` or `__pointer__` for the mode used to represent pointers.

`objc_root_class` (Objective-C and Objective-C++ only)
: This attribute marks a class as being a root class, and thus allows the compiler to elide any warnings about a missing superclass and to make additional checks for mandatory methods as needed.

`packed`
: This attribute, attached to a `struct`, `union`, or C++ `class` type definition, specifies that each of its members (other than zero-width bit-fields) is placed to minimize the memory required. This is equivalent to specifying the `packed` attribute on each of the members.

  When attached to an `enum` definition, the `packed` attribute indicates that the smallest integral type should be used. Specifying the `-fshort-enums` flag on the command line is equivalent to specifying the `packed` attribute on all `enum` definitions.

  In the following example `struct my_packed_struct`'s members are packed closely together, but the internal layout of its `s` member is not packed—to do that, `struct my_unpacked_struct` needs to be packed too.

```
struct my_unpacked_struct
 {
    char c;
    int i;
 };

struct __attribute__ ((__packed__)) my_packed_struct
  {
     char c;
     int  i;
     struct my_unpacked_struct s;
  };
```

  You may only specify the `packed` attribute on the definition of an `enum`, `struct`, `union`, or `class`, not on a `typedef` that does not also define the enumerated type, structure, union, or class.

`scalar_storage_order ("`*endianness*`")`

When attached to a `union` or a `struct`, this attribute sets the storage order, aka endianness, of the scalar fields of the type, as well as the array fields whose component is scalar. The supported endiannesses are `big-endian` and `little-endian`. The attribute has no effects on fields which are themselves a `union`, a `struct` or an array whose component is a `union` or a `struct`, and it is possible for these fields to have a different scalar storage order than the enclosing type.

Note that neither pointer nor vector fields are considered scalar fields in this context, so the attribute has no effects on these fields.

This attribute is supported only for targets that use a uniform default scalar storage order (fortunately, most of them), i.e. targets that store the scalars either all in big-endian or all in little-endian.

Additional restrictions are enforced for types with the reverse scalar storage order with regard to the scalar storage order of the target:

- Taking the address of a scalar field of a `union` or a `struct` with reverse scalar storage order is not permitted and yields an error.
- Taking the address of an array field, whose component is scalar, of a `union` or a `struct` with reverse scalar storage order is permitted but yields a warning, unless `-Wno-scalar-storage-order` is specified.
- Taking the address of a `union` or a `struct` with reverse scalar storage order is permitted.

These restrictions exist because the storage order attribute is lost when the address of a scalar or the address of an array with scalar component is taken, so storing indirectly through this address generally does not work. The second case is nevertheless allowed to be able to perform a block copy from or to the array.

Moreover, the use of type punning or aliasing to toggle the storage order is not supported; that is to say, if a given scalar object can be accessed through distinct types that assign a different storage order to it, then the behavior is undefined.

`strub`

This attribute defines stack-scrubbing properties of functions and variables, so that functions that access sensitive data can have their stack frames zeroed-out upon returning or propagating exceptions. This may be enabled explicitly, by selecting certain `strub` modes for specific functions, or implicitly, by means of `strub` variables.

Being a type attribute, it attaches to types, even when specified in function and variable declarations. When applied to function types, it takes an optional string argument. When applied to a pointer-to-function type, if the optional argument is given, it gets propagated to the function type.

```
/* A strub variable.  */
int __attribute__ ((strub)) var;
/* A strub variable that happens to be a pointer.  */
__attribute__ ((strub)) int *strub_ptr_to_int;
/* A pointer type that may point to a strub variable.  */
typedef int __attribute__ ((strub)) *ptr_to_strub_int_type;
```

```
/* A declaration of a strub function.  */
extern int __attribute__ ((strub)) foo (void);
/* A pointer to that strub function.  */
int __attribute__ ((strub ("at-calls"))) (*ptr_to_strub_fn)(void) = foo;
```

A function associated with `at-calls strub` mode (`strub("at-calls")`, or just `strub`) undergoes interface changes. Its callers are adjusted to match the changes, and to scrub (overwrite with zeros) the stack space used by the called function after it returns. The interface change makes the function type incompatible with an unadorned but otherwise equivalent type, so *every* declaration and every type that may be used to call the function must be associated with this strub mode.

A function associated with `internal strub` mode (`strub("internal")`) retains an unmodified, type-compatible interface, but it may be turned into a wrapper that calls the wrapped body using a custom interface. The wrapper then scrubs the stack space used by the wrapped body. Though the wrapped body has its stack space scrubbed, the wrapper does not, so arguments and return values may remain unscrubbed even when such a function is called by another function that enables `strub`. This is why, when compiling with `-fstrub=strict`, a `strub` context is not allowed to call `internal strub` functions.

```
/* A declaration of an internal-strub function.  */
extern int __attribute__ ((strub ("internal"))) bar (void);

int __attribute__ ((strub))
baz (void)
{
  /* Ok, foo was declared above as an at-calls strub function.  */
  foo ();
  /* Not allowed in strict mode, otherwise allowed.  */
  bar ();
}
```

An automatically-allocated variable associated with the `strub` attribute causes the (immediately) enclosing function to have `strub` enabled.

A statically-allocated variable associated with the `strub` attribute causes functions that *read* it, through its `strub` data type, to have `strub` enabled. Reading data by dereferencing a pointer to a `strub` data type has the same effect. Note: The attribute does not carry over from a composite type to the types of its components, so the intended effect may not be obtained with non-scalar types.

When selecting a `strub`-enabled mode for a function that is not explicitly associated with one, because of `strub` variables or data pointers, the function must satisfy `internal` mode viability requirements (see below), even when `at-calls` mode is also viable and, being more efficient, ends up selected as an optimization.

```
/* zapme is implicitly strub-enabled because of strub variables.
   Optimization may change its strub mode, but not the requirements.  */
static int
zapme (int i)
{
  /* A local strub variable enables strub.  */
```

```
  int __attribute__ ((strub)) lvar;
  /* Reading strub data through a pointer-to-strub enables strub.  */
  lvar = * (ptr_to_strub_int_type) &i;
  /* Writing to a global strub variable does not enable strub.  */
  var = lvar;
  /* Reading from a global strub variable enables strub.  */
  return var;
}
```

A `strub` context is the body (as opposed to the interface) of a function that has `strub` enabled, be it explicitly, by `at-calls` or `internal` mode, or implicitly, due to `strub` variables or command-line options.

A function of a type associated with the `disabled` `strub` mode (`strub("disabled")` will not have its own stack space scrubbed. Such functions *cannot* be called from within `strub` contexts.

In order to enable a function to be called from within `strub` contexts without having its stack space scrubbed, associate it with the `callable` `strub` mode (`strub("callable")`).

When a function is not assigned a `strub` mode, explicitly or implicitly, the mode defaults to `callable`, except when compiling with `-fstrub=strict`, that causes `strub` mode to default to `disabled`.

```
extern int __attribute__ ((strub ("callable"))) bac (void);
extern int __attribute__ ((strub ("disabled"))) bad (void);
 /* Implicitly disabled with -fstrub=strict, otherwise callable.  */
extern int bah (void);

int __attribute__ ((strub))
bal (void)
{
  /* Not allowed, bad is not strub-callable.  */
  bad ();
  /* Ok, bac is strub-callable.  */
  bac ();
  /* Not allowed with -fstrub=strict, otherwise allowed.  */
  bah ();
}
```

Function types marked `callable` and `disabled` are not mutually compatible types, but the underlying interfaces are compatible, so it is safe to convert pointers between them, and to use such pointers or alternate declarations to call them. Interfaces are also interchangeable between them and `internal` (but not `at-calls`!), but adding `internal` to a pointer type will not cause the pointed-to function to perform stack scrubbing.

```
void __attribute__ ((strub))
bap (void)
{
  /* Assign a callable function to pointer-to-disabled.
     Flagged as not quite compatible with -Wpedantic.  */
  int __attribute__ ((strub ("disabled"))) (*d_p) (void) = bac;
```

```
  /* Not allowed: calls disabled type in a strub context.  */
  d_p ();

  /* Assign a disabled function to pointer-to-callable.
     Flagged as not quite compatible with -Wpedantic.  */
  int __attribute__ ((strub ("callable"))) (*c_p) (void) = bad;
  /* Ok, safe.  */
  c_p ();

  /* Assign an internal function to pointer-to-callable.
     Flagged as not quite compatible with -Wpedantic.  */
  c_p = bar;
  /* Ok, safe.  */
  c_p ();

  /* Assign an at-calls function to pointer-to-callable.
     Flaggged as incompatible.  */
  c_p = bal;
  /* The call through an interface-incompatible type will not use the
     modified interface expected by the at-calls function, so it is
     likely to misbehave at runtime.  */
  c_p ();
}
```

`Strub` contexts are never inlined into non-`strub` contexts. When an `internal`-strub function is split up, the wrapper can often be inlined, but the wrapped body *never* is. A function marked as `always_inline`, even if explicitly assigned `internal` strub mode, will not undergo wrapping, so its body gets inlined as required.

```
inline int __attribute__ ((strub ("at-calls")))
inl_atc (void)
{
  /* This body may get inlined into strub contexts.  */
}

inline int __attribute__ ((strub ("internal")))
inl_int (void)
{
  /* This body NEVER gets inlined, though its wrapper may.  */
}

inline int __attribute__ ((strub ("internal"), always_inline))
inl_int_ali (void)
{
  /* No internal wrapper, so this body ALWAYS gets inlined,
     but it cannot be called from non-strub contexts.  */
}
```

```
void __attribute__ ((strub ("disabled")))
bat (void)
{
  /* Not allowed, cannot inline into a non-strub context.  */
  inl_int_ali ();
}
```

Some `-fstrub=*` command-line options enable `strub` modes implicitly where viable. A `strub` mode is only viable for a function if the function is eligible for that mode, and if other conditions, detailed below, are satisfied. If it's not eligible for a mode, attempts to explicitly associate it with that mode are rejected with an error message. If it is eligible, that mode may be assigned explicitly through this attribute, but implicit assignment through command-line options may involve additional viability requirements.

A function is ineligible for `at-calls strub` mode if a different `strub` mode is explicitly requested, if attribute `noipa` is present, or if it calls `__builtin_apply_args`. `At-calls strub` mode, if not requested through the function type, is only viable for an eligible function if the function is not visible to other translation units, if it doesn't have its address taken, and if it is never called with a function type overrider.

```
/* bar is eligible for at-calls strub mode,
   but not viable for that mode because it is visible to other units.
   It is eligible and viable for internal strub mode.  */
void bav () {}

/* setp is eligible for at-calls strub mode,
   but not viable for that mode because its address is taken.
   It is eligible and viable for internal strub mode.  */
void setp (void) { static void (*p)(void); = setp; }
```

A function is ineligible for `internal strub` mode if a different `strub` mode is explicitly requested, or if attribute `noipa` is present. For an `always_inline` function, meeting these requirements is enough to make it eligible. Any function that has attribute `noclone`, that uses such extensions as non-local labels, computed gotos, alternate variable argument passing interfaces, `__builtin_next_arg`, or `__builtin_return_address`, or that takes too many (about 64Ki) arguments is ineligible, unless it is `always_inline`. For `internal strub` mode, all eligible functions are viable.

```
/* flop is not eligible, thus not viable, for at-calls strub mode.
   Likewise for internal strub mode.  */
__attribute__ ((noipa)) void flop (void) {}

/* flip is eligible and viable for at-calls strub mode.
   It would be ineligible for internal strub mode, because of noclone,
   if it weren't for always_inline.  With always_inline, noclone is not
   an obstacle, so it is also eligible and viable for internal strub mode.  */
inline __attribute__ ((noclone, always_inline)) void flip (void) {}
```

`transparent_union`

This attribute, attached to a `union` type definition, indicates that any function parameter having that union type causes calls to that function to be treated in a special way.

First, the argument corresponding to a transparent union type can be of any type in the union; no cast is required. Also, if the union contains a pointer type, the corresponding argument can be a null pointer constant or a void pointer expression; and if the union contains a void pointer type, the corresponding argument can be any pointer expression. If the union member type is a pointer, qualifiers like `const` on the referenced type must be respected, just as with normal pointer conversions.

Second, the argument is passed to the function using the calling conventions of the first member of the transparent union, not the calling conventions of the union itself. All members of the union must have the same machine representation; this is necessary for this argument passing to work properly.

Transparent unions are designed for library functions that have multiple interfaces for compatibility reasons. For example, suppose the `wait` function must accept either a value of type `int *` to comply with POSIX, or a value of type `union wait *` to comply with the 4.1BSD interface. If `wait`'s parameter were `void *`, `wait` would accept both kinds of arguments, but it would also accept any other pointer type and this would make argument type checking less useful. Instead, `<sys/wait.h>` might define the interface as follows:

```
typedef union __attribute__ ((__transparent_union__))
  {
    int *__ip;
    union wait *__up;
  } wait_status_ptr_t;

pid_t wait (wait_status_ptr_t);
```

This interface allows either `int *` or `union wait *` arguments to be passed, using the `int *` calling convention. The program can call `wait` with arguments of either type:

```
int w1 () { int w; return wait (&w); }
int w2 () { union wait w; return wait (&w); }
```

With this interface, `wait`'s implementation might look like this:

```
pid_t wait (wait_status_ptr_t p)
{
  return waitpid (-1, p.__ip, 0);
}
```

`unavailable`
`unavailable (`*`msg`*`)`

The `unavailable` attribute behaves in the same manner as the `deprecated` one, but emits an error rather than a warning. It is used to indicate that a (perhaps previously `deprecated`) type is no longer usable.

The `unavailable` attribute can also be used for functions and variables (see Section 6.4.1 [Function Attributes], page 621, see Section 6.4.2 [Variable Attributes], page 699.)

`unused` When attached to a type (including a `union` or a `struct`), this attribute means that variables of that type are meant to appear possibly unused. GCC does not produce a warning for any variables of that type, even if the variable appears to do nothing. This is often the case with lock or thread classes, which are usually defined and then not referenced, but contain constructors and destructors that have nontrivial bookkeeping functions.

`vector_size (`*bytes*`)`
This attribute specifies the vector size for the type, measured in bytes. The type to which it applies is known as the *base type*. The *bytes* argument must be a positive power-of-two multiple of the base type size. For example, the following declarations:

```
typedef __attribute__ ((vector_size (32))) int int_vec32_t ;
typedef __attribute__ ((vector_size (32))) int* int_vec32_ptr_t;
typedef __attribute__ ((vector_size (32))) int int_vec32_arr3_t[3];
```

define `int_vec32_t` to be a 32-byte vector type composed of `int` sized units. With `int` having a size of 4 bytes, the type defines a vector of eight units, four bytes each. The mode of variables of type `int_vec32_t` is `V8SI`. `int_vec32_ptr_t` is then defined to be a pointer to such a vector type, and `int_vec32_arr3_t` to be an array of three such vectors. See Section 7.8 [Vector Extensions], page 850, for details of manipulating objects of vector types.

This attribute is only applicable to integral and floating scalar types. In function declarations the attribute applies to the function return type.

For example, the following:

```
__attribute__ ((vector_size (16))) float get_flt_vec16 (void);
```

declares `get_flt_vec16` to be a function returning a 16-byte vector with the base type `float`.

`visibility`
In C++, attribute visibility (see Section 6.4.1 [Function Attributes], page 621) can also be applied to class, struct, union and enum types. Unlike other type attributes, the attribute must appear between the initial keyword and the name of the type; it cannot appear after the body of the type.

Note that the type visibility is applied to vague linkage entities associated with the class (vtable, typeinfo node, etc.). In particular, if a class is thrown as an exception in one shared object and caught in another, the class must have default visibility. Otherwise the two shared objects are unable to use the same typeinfo node and exception handling will break.

`warn_if_not_aligned (`*alignment*`)`
This attribute specifies a threshold for the structure field, measured in bytes. If the structure field is aligned below the threshold, a warning will be issued. For example, the declaration:

```
typedef unsigned long long __u64
   __attribute__((aligned (4), warn_if_not_aligned (8)));

struct foo
{
  int i1;
```

```
  int i2;
  __u64 x;
};
```

causes the compiler to issue an warning on `struct foo`, like '`warning: alignment 4 of 'struct foo' is less than 8`'. It is used to define `struct foo` in such a way that `struct foo` has the same layout and the structure field `x` has the same alignment when `__u64` is aligned at either 4 or 8 bytes. Align `struct foo` to 8 bytes:

```
struct __attribute__ ((aligned (8))) foo
{
  int i1;
  int i2;
  __u64 x;
};
```

silences the warning. The compiler also issues a warning, like '`warning: 'x' offset 12 in 'struct foo' isn't aligned to 8`', when the structure field has the misaligned offset:

```
struct __attribute__ ((aligned (8))) foo
{
  int i1;
  int i2;
  int i3;
  __u64 x;
};
```

This warning can be disabled by `-Wno-if-not-aligned`.

To specify multiple attributes, separate them by commas within the double parentheses: for example, '`__attribute__ ((aligned (16), packed))`'.

6.4.3.2 ARC Type Attributes

Declaring objects with `uncached` allows you to exclude data-cache participation in load and store operations on those objects without involving the additional semantic implications of `volatile`. The `.di` instruction suffix is used for all loads and stores of data declared `uncached`.

6.4.3.3 ARM Type Attributes

On those ARM targets that support `dllimport` (such as Symbian OS), you can use the `notshared` attribute to indicate that the virtual table and other similar data for a class should not be exported from a DLL. For example:

```
class __declspec(notshared) C {
public:
  __declspec(dllimport) C();
  virtual void f();
}

__declspec(dllexport)
C::C() {}
```

In this code, `C::C` is exported from the current DLL, but the virtual table for `C` is not exported. (You can use `__attribute__` instead of `__declspec` if you prefer, but most Symbian OS code uses `__declspec`.)

6.4.3.4 BPF Type Attributes

BPF Compile Once - Run Everywhere (CO-RE) support. When attached to a `struct` or `union` type definition, indicates that CO-RE relocation information should be generated for any access to a variable of that type. The behavior is equivalent to the programmer manually wrapping every such access with `__builtin_preserve_access_index`.

6.4.3.5 PowerPC Type Attributes

Three attributes currently are defined for PowerPC configurations: `altivec`, `ms_struct` and `gcc_struct`.

For full documentation of the `ms_struct` and `gcc_struct` attributes please see the documentation in Section 6.4.3.6 [x86 Type Attributes], page 730.

The `altivec` attribute allows one to declare AltiVec vector data types supported by the AltiVec Programming Interface Manual. The attribute requires an argument to specify one of three vector types: `vector__`, `pixel__` (always followed by unsigned short), and `bool__` (always followed by unsigned).

```
__attribute__((altivec(vector__)))
__attribute__((altivec(pixel__))) unsigned short
__attribute__((altivec(bool__))) unsigned
```

These attributes mainly are intended to support the `__vector`, `__pixel`, and `__bool` AltiVec keywords.

6.4.3.6 x86 Type Attributes

Two attributes are currently defined for x86 configurations: `ms_struct` and `gcc_struct`.

`ms_struct`
`gcc_struct`

If `packed` is used on a structure, or if bit-fields are used it may be that the Microsoft ABI packs them differently than GCC normally packs them. Particularly when moving packed data between functions compiled with GCC and the native Microsoft compiler (either via function call or as data in a file), it may be necessary to access either format.

The `ms_struct` and `gcc_struct` attributes correspond to the `-mms-bitfields` and `-mno-ms-bitfields` command-line options, respectively; see Section 3.20.54 [x86 Options], page 534, for details of how structure layout is affected. See Section 6.4.2.15 [x86 Variable Attributes], page 714, for information about the corresponding attributes on variables.

6.4.4 Label Attributes

GCC allows attributes to be set on C labels. See Section 6.4.7 [Attribute Syntax], page 734, for details of the exact syntax for using attributes. Other attributes are available for functions (see Section 6.4.1 [Function Attributes], page 621), variables (see Section 6.4.2 [Variable Attributes], page 699), enumerators (see Section 6.4.5 [Enumerator Attributes], page 731), statements (see Section 6.4.6 [Statement Attributes], page 732), and for types (see Section 6.4.3 [Type Attributes], page 715). A label attribute followed by a declaration appertains to the label and not the declaration.

This example uses the `cold` label attribute to indicate the `ErrorHandling` branch is unlikely to be taken and that the `ErrorHandling` label is unused:

```
    asm goto ("some asm" : : : : NoError);

/* This branch (the fall-through from the asm) is less commonly used */
ErrorHandling:
    __attribute__((cold, unused)); /* Semi-colon is required here */
    printf("error\n");
    return 0;

NoError:
    printf("no error\n");
    return 1;
```

`unused` This feature is intended for program-generated code that may contain unused labels, but which is compiled with `-Wall`. It is not normally appropriate to use it in human-written code, though it could be useful in cases where the code that jumps to the label is contained within an `#ifdef` conditional.

`hot` The `hot` attribute on a label is used to inform the compiler that the path following the label is more likely than paths that are not so annotated. This attribute is used in cases where `__builtin_expect` cannot be used, for instance with computed goto or `asm goto`.

`cold` The `cold` attribute on labels is used to inform the compiler that the path following the label is unlikely to be executed. This attribute is used in cases where `__builtin_expect` cannot be used, for instance with computed goto or `asm goto`.

6.4.5 Enumerator Attributes

GCC allows attributes to be set on enumerators. See Section 6.4.7 [Attribute Syntax], page 734, for details of the exact syntax for using attributes. Other attributes are available for functions (see Section 6.4.1 [Function Attributes], page 621), variables (see Section 6.4.2 [Variable Attributes], page 699), labels (see Section 6.4.4 [Label Attributes], page 730), statements (see Section 6.4.6 [Statement Attributes], page 732), and for types (see Section 6.4.3 [Type Attributes], page 715).

This example uses the `deprecated` enumerator attribute to indicate the `oldval` enumerator is deprecated:

```
enum E {
  oldval __attribute__((deprecated)),
  newval
};

int
fn (void)
{
  return oldval;
}
```

`deprecated`
The `deprecated` attribute results in a warning if the enumerator is used anywhere in the source file. This is useful when identifying enumerators that are

expected to be removed in a future version of a program. The warning also includes the location of the declaration of the deprecated enumerator, to enable users to easily find further information about why the enumerator is deprecated, or what they should do instead. Note that the warnings only occurs for uses.

`unavailable`
: The `unavailable` attribute results in an error if the enumerator is used anywhere in the source file. In other respects it behaves in the same manner as the `deprecated` attribute.

6.4.6 Statement Attributes

GCC allows attributes to be set on statements. See Section 6.4.7 [Attribute Syntax], page 734, for details of the exact syntax for using attributes. Other attributes are available for functions (see Section 6.4.1 [Function Attributes], page 621), variables (see Section 6.4.2 [Variable Attributes], page 699), labels (see Section 6.4.4 [Label Attributes], page 730), enumerators (see Section 6.4.5 [Enumerator Attributes], page 731), and for types (see Section 6.4.3 [Type Attributes], page 715).

`fallthrough`
: The `fallthrough` attribute with a null statement serves as a fallthrough statement. It hints to the compiler that a statement that falls through to another case label, or user-defined label in a switch statement is intentional and thus the `-Wimplicit-fallthrough` warning must not trigger. The fallthrough attribute may appear at most once in each attribute list, and may not be mixed with other attributes. It can only be used in a switch statement (the compiler will issue an error otherwise), after a preceding statement and before a logically succeeding case label, or user-defined label.

  This example uses the `fallthrough` statement attribute to indicate that the `-Wimplicit-fallthrough` warning should not be emitted:

```
switch (cond)
  {
  case 1:
    bar (1);
    __attribute__((fallthrough));
  case 2:
    ...
  }
```

`assume`
: The `assume` attribute with a null statement serves as portable assumption. It should have a single argument, a conditional expression, which is not evaluated. If the argument would evaluate to true at the point where it appears, it has no effect, otherwise there is undefined behavior. This is a GNU variant of the ISO C++23 standard `assume` attribute, but it can be used in any version of both C and C++.

```
int
foo (int x, int y)
{
  __attribute__((assume(x == 42)));
  __attribute__((assume(++y == 43)));
  return x + y;
}
```

y is not actually incremented and the compiler can but does not have to optimize it to just `return 42 + 42;`.

`musttail`

The `gnu::musttail` or `clang::musttail` standard attribute or `musttail` GNU attribute can be applied to a `return` statement with a return-value expression that is a function call. It asserts that the call must be a tail call that does not allocate extra stack space, so it is safe to use tail recursion to implement long-running loops.

```
[[gnu::musttail]] return foo();
```

```
__attribute__((musttail)) return bar();
```

If the compiler cannot generate a `musttail` tail call it reports an error. On some targets, tail calls may not be supported at all. The `musttail` attribute asserts that the lifetime of automatic variables, function parameters and temporaries (unless they have non-trivial destruction) can end before the actual call instruction, and that any access to those from inside of the called function results is considered undefined behavior. Enabling `-O1` or `-O2` can improve the success of tail calls.

```
int foo (int *);
void bar (int *);
struct S { S (); ~S (); int s; };

int
baz (int *x)
{
  if (*x == 1)
    {
      int a = 42;
      /* The call is a tail call (would not be without the
         attribute).  Dereferencing the pointer in the callee is
         undefined behavior, and there is a warning emitted
         for this by default (-Wmusttail-local-addr).  */
      [[gnu::musttail]] return foo (&a);
    }
  else if (*x == 2)
    {
      int a = 42;
      bar (&a);
      /* The call is a tail call (would not be without the
         attribute).  If bar stores the pointer anywhere, dereferencing
         it in foo is undefined behavior.  There is a warning
         emitted for this with -Wextra, which implies
         -Wmaybe-musttail-local-addr.  */
      [[gnu::musttail]] return foo (nullptr);
    }
  else
    {
      S s;
      /* The s variable requires non-trivial destruction which ought
         to be performed after the foo call returns, so this is
         rejected.  */
      [[gnu::musttail]] return foo (&s.s);
    }
}
```

To avoid the -Wmaybe-musttail-local-addr warning in the above *x == 2 case and similar code, consider defining the maybe-escaped variables in a separate scope that ends before the return statement, if that is possible, to make it clear that the variable is not live during the call. So:

```
else if (*x == 2)
  {
    {
      int a = 42;
      bar (&a);
    }
    /* The call is a tail call (would not be without the
       attribute).  If bar stores the pointer anywhere, dereferencing
       it in foo is undefined behavior even without tail call
       optimization, and there is no warning.  */
    [[gnu::musttail]] return foo (nullptr);
  }
```

It is not possible to avoid the warning in this way if the maybe-escaped variable is a function argument, because those are in scope for the whole function.

6.4.7 Attribute Syntax

GCC provides two different ways to specify attributes: the standard C and C++ syntax using double square brackets, and the older GNU extension syntax using the __attribute__ keyword, which predates the adoption of the standard syntax and is still widely used in older code.

The standard '[[]]' attribute syntax is recognized by GCC's default language dialect for both C and C++. More specifically, this syntax was first introduced in the C++11 language standard (see Chapter 2 [Standards], page 3), and is supported by GCC in C++ code with -std=c++11 or -std=gnu++11 or later. It is also part of the C23 language standard and is supported when compiling C code with -std=c23 or -std=gnu17 or later.

When using GNU-specific attributes in the standard syntax, you must prefix their names with 'gnu::', such as gnu::section. Refer to the relevant language standards for exact details on the placement of '[[]]' attributes within your code, as they differ in some details from the rules for the GNU attribute syntax.

With the -fopenmp option, GCC additionally recognizes OpenMP directives, with names prefixed with 'omp::', using the standard '[[]]' syntax. See Section 6.7 [OpenMP], page 749.

The remainder of this section describes the details of the GNU extension __attribute__ syntax, and the constructs to which attribute specifiers bind, for the C language. Some details may vary for C++ and Objective-C. Because of limitations in the grammar for attributes, some forms described here may not be successfully parsed in all cases.

There are some problems with the semantics of attributes in C++. For example, there are no manglings for attributes, although they may affect code generation, so problems may arise when attributed types are used in conjunction with templates or overloading. Similarly, typeid does not distinguish between types with different attributes. Support for attributes in C++ may be restricted in future to attributes on declarations only, but not on nested declarators.

See Section 6.4.1 [Function Attributes], page 621, for details of the semantics of attributes applying to functions. See Section 6.4.2 [Variable Attributes], page 699, for details of the semantics of attributes applying to variables. See Section 6.4.3 [Type Attributes], page 715, for details of the semantics of attributes applying to structure, union and enumerated types. See Section 6.4.4 [Label Attributes], page 730, for details of the semantics of attributes applying to labels. See Section 6.4.5 [Enumerator Attributes], page 731, for details of the semantics of attributes applying to enumerators. See Section 6.4.6 [Statement Attributes], page 732, for details of the semantics of attributes applying to statements.

An *attribute specifier* is of the form `__attribute__ ((attribute-list))`. An *attribute list* is a possibly empty comma-separated sequence of *attributes*, where each attribute is one of the following:

- Empty. Empty attributes are ignored.
- An attribute name (which may be an identifier such as `unused`, or a reserved word such as `const`).
- An attribute name followed by a parenthesized list of parameters for the attribute. These parameters take one of the following forms:
  - An identifier. For example, `mode` attributes use this form.
  - An identifier followed by a comma and a non-empty comma-separated list of expressions. For example, `format` attributes use this form.
  - A possibly empty comma-separated list of expressions. For example, `format_arg` attributes use this form with the list being a single integer constant expression, and `alias` attributes use this form with the list being a single string constant.

An *attribute specifier list* is a sequence of one or more attribute specifiers, not separated by any other tokens.

You may optionally specify attribute names with '`__`' preceding and following the name. This allows you to use them in header files without being concerned about a possible macro of the same name. For example, you may use the attribute name `__noreturn__` instead of `noreturn`.

Label Attributes

In GNU C, an attribute specifier list may appear after the colon following a label, other than a `case` or `default` label. GNU C++ only permits attributes on labels if the attribute specifier is immediately followed by a semicolon (i.e., the label applies to an empty statement). If the semicolon is missing, C++ label attributes are ambiguous, as it is permissible for a declaration, which could begin with an attribute list, to be labelled in C++. Declarations cannot be labelled in C90 or C99, so the ambiguity does not arise there.

Enumerator Attributes

In GNU C, an attribute specifier list may appear as part of an enumerator. The attribute goes after the enumeration constant, before '`=`', if present. The optional attribute in the enumerator appertains to the enumeration constant. It is not possible to place the attribute after the constant expression, if present.

Statement Attributes

In GNU C, an attribute specifier list may appear as part of a null statement. The attribute goes before the semicolon. Some attributes in new style syntax are also supported on non-null statements.

Type Attributes

An attribute specifier list may appear as part of a `struct`, `union` or `enum` specifier. It may go either immediately after the `struct`, `union` or `enum` keyword, or after the closing brace. The former syntax is preferred. Where attribute specifiers follow the closing brace, they are considered to relate to the structure, union or enumerated type defined, not to any enclosing declaration the type specifier appears in, and the type defined is not complete until after the attribute specifiers.

All other attributes

Otherwise, an attribute specifier appears as part of a declaration, counting declarations of unnamed parameters and type names, and relates to that declaration (which may be nested in another declaration, for example in the case of a parameter declaration), or to a particular declarator within a declaration. Where an attribute specifier is applied to a parameter declared as a function or an array, it should apply to the function or array rather than the pointer to which the parameter is implicitly converted, but this is not yet correctly implemented.

Any list of specifiers and qualifiers at the start of a declaration may contain attribute specifiers, whether or not such a list may in that context contain storage class specifiers. (Some attributes, however, are essentially in the nature of storage class specifiers, and only make sense where storage class specifiers may be used; for example, `section`.) There is one necessary limitation to this syntax: the first old-style parameter declaration in a function definition cannot begin with an attribute specifier, because such an attribute applies to the function instead by syntax described below (which, however, is not yet implemented in this case). In some other cases, attribute specifiers are permitted by this grammar but not yet supported by the compiler. All attribute specifiers in this place relate to the declaration as a whole. In the obsolescent usage where a type of `int` is implied by the absence of type specifiers, such a list of specifiers and qualifiers may be an attribute specifier list with no other specifiers or qualifiers.

At present, the first parameter in a function prototype must have some type specifier that is not an attribute specifier; this resolves an ambiguity in the interpretation of `void f(int (__attribute__((foo)) x))`, but is subject to change. At present, if the parentheses of a function declarator contain only attributes then those attributes are ignored, rather than yielding an error or warning or implying a single parameter of type int, but this is subject to change.

An attribute specifier list may appear immediately before a declarator (other than the first) in a comma-separated list of declarators in a declaration of more than one identifier using a single list of specifiers and qualifiers. Such attribute specifiers apply only to the identifier before whose declarator they appear. For example, in

```
__attribute__((noreturn)) void d0 (void),
    __attribute__((format(printf, 1, 2))) d1 (const char *, ...),
     d2 (void);
```

the `noreturn` attribute applies to all the functions declared; the `format` attribute only applies to `d1`.

An attribute specifier list may appear immediately before the comma, '`=`', or semicolon terminating the declaration of an identifier other than a function definition. Such attribute specifiers apply to the declared object or function. Where an assembler name for an object or function is specified (see Section 6.11.5 [Asm Labels], page 806), the attribute must follow the `asm` specification.

An attribute specifier list may, in future, be permitted to appear after the declarator in a function definition (before any old-style parameter declarations or the function body).

Attribute specifiers may be mixed with type qualifiers appearing inside the `[]` of a parameter array declarator, in the C99 construct by which such qualifiers are applied to the pointer to which the array is implicitly converted. Such attribute specifiers apply to the pointer, not to the array, but at present this is not implemented and they are ignored.

An attribute specifier list may appear at the start of a nested declarator. At present, there are some limitations in this usage: the attributes correctly apply to the declarator, but for most individual attributes the semantics this implies are not implemented. When attribute specifiers follow the `*` of a pointer declarator, they may be mixed with any type qualifiers present. The following describes the formal semantics of this syntax. It makes the most sense if you are familiar with the formal specification of declarators in the ISO C standard.

Consider (as in C99 subclause 6.7.5 paragraph 4) a declaration `T D1`, where `T` contains declaration specifiers that specify a type *Type* (such as `int`) and `D1` is a declarator that contains an identifier *ident*. The type specified for *ident* for derived declarators whose type does not include an attribute specifier is as in the ISO C standard.

If `D1` has the form `(` *`attribute-specifier-list`* `D )`, and the declaration `T D` specifies the type "*derived-declarator-type-list Type*" for *ident*, then `T D1` specifies the type "*derived-declarator-type-list attribute-specifier-list Type*" for *ident*.

If `D1` has the form `*` *`type-qualifier-and-attribute-specifier-list`* `D`, and the declaration `T D` specifies the type "*derived-declarator-type-list Type*" for *ident*, then `T D1` specifies the type "*derived-declarator-type-list type-qualifier-and-attribute-specifier-list* pointer to *Type*" for *ident*.

For example,

```
void (__attribute__((noreturn)) ****f) (void);
```

specifies the type "pointer to pointer to pointer to pointer to non-returning function returning `void`". As another example,

```
char *__attribute__((aligned(8))) *f;
```

specifies the type "pointer to 8-byte-aligned pointer to `char`". Note again that this does not work with most attributes; for example, the usage of '`aligned`' and '`noreturn`' attributes given above is not yet supported.

For compatibility with existing code written for compiler versions that did not implement attributes on nested declarators, some laxity is allowed in the placing of attributes. If an attribute that only applies to types is applied to a declaration, it is treated as applying to the type of that declaration. If an attribute that only applies to declarations is applied to the type of a declaration, it is treated as applying to that declaration; and, for compatibility with code placing the attributes immediately before the identifier declared, such an attribute applied to a function return type is treated as applying to the function type, and such an attribute applied to an array element type is treated as applying to the array type. If an attribute that only applies to function types is applied to a pointer-to-function type, it is treated as applying to the pointer target type; if such an attribute is applied to a function return type that is not a pointer-to-function type, it is treated as applying to the function type.

6.5 Pragmas Accepted by GCC

GCC supports several types of pragmas, primarily in order to compile code originally written for other compilers. Note that in general we do not recommend the use of pragmas; See Section 6.4.1 [Function Attributes], page 621, for further explanation.

The GNU C preprocessor recognizes several pragmas in addition to the compiler pragmas documented here. Refer to the CPP manual for more information.

GCC additionally recognizes OpenMP pragmas when the `-fopenmp` option is specified, and OpenACC pragmas when the `-fopenacc` option is specified. See Section 6.7 [OpenMP], page 749, and Section 6.8 [OpenACC], page 750.

6.5.1 AArch64 Pragmas

The pragmas defined by the AArch64 target correspond to the AArch64 target function attributes. They can be specified as below:

```
#pragma GCC target("string")
```

where *string* can be any string accepted as an AArch64 target attribute. See Section 6.4.1.2 [AArch64 Function Attributes], page 652, for more details on the permissible values of `string`.

6.5.2 ARM Pragmas

The ARM target defines pragmas for controlling the default addition of `long_call` and `short_call` attributes to functions. See Section 6.4.1 [Function Attributes], page 621, for information about the effects of these attributes.

`long_calls`
: Set all subsequent functions to have the `long_call` attribute.

`no_long_calls`
: Set all subsequent functions to have the `short_call` attribute.

`long_calls_off`
: Do not affect the `long_call` or `short_call` attributes of subsequent functions.

6.5.3 LoongArch Pragmas

The list of attributes supported by Pragma is the same as that of target function attributes. See Section 6.4.1.13 [LoongArch Function Attributes], page 665.

Example:

```
#pragma GCC target("strict-align")
```

6.5.4 M32C Pragmas

`GCC memregs` *number*
: Overrides the command-line option `-memregs=` for the current file. Use with care! This pragma must be before any function in the file, and mixing different memregs values in different objects may make them incompatible. This pragma

is useful when a performance-critical function uses a memreg for temporary values, as it may allow you to reduce the number of memregs used.

`ADDRESS` *name address*

For any declared symbols matching *name*, this does three things to that symbol: it forces the symbol to be located at the given address (a number), it forces the symbol to be volatile, and it changes the symbol's scope to be static. This pragma exists for compatibility with other compilers, but note that the common `1234H` numeric syntax is not supported (use `0x1234` instead). Example:

```
#pragma ADDRESS port3 0x103
char port3;
```

6.5.5 PRU Pragmas

`ctable_entry` *index constant_address*

Specifies that the PRU CTABLE entry given by *index* has the value *constant_address*. This enables GCC to emit LBCO/SBCO instructions when the load/store address is known and can be addressed with some CTABLE entry. For example:

```
/* will compile to "sbco Rx, 2, 0x10, 4" */
#pragma ctable_entry 2 0x4802a000
*(unsigned int *)0x4802a010 = val;
```

6.5.6 RS/6000 and PowerPC Pragmas

The RS/6000 and PowerPC targets define one pragma for controlling whether or not the `longcall` attribute is added to function declarations by default. This pragma overrides the `-mlongcall` option, but not the `longcall` and `shortcall` attributes. See Section 3.20.42 [RS/6000 and PowerPC Options], page 493, for more information about when long calls are and are not necessary.

`longcall (1)`

Apply the `longcall` attribute to all subsequent function declarations.

`longcall (0)`

Do not apply the `longcall` attribute to subsequent function declarations.

6.5.7 S/390 Pragmas

The pragmas defined by the S/390 target correspond to the S/390 target function attributes and some the additional options:

'`zvector`'
'`no-zvector`'

Note that options of the pragma, unlike options of the target attribute, do change the value of preprocessor macros like `__VEC__`. They can be specified as below:

```
#pragma GCC target("string[,string]...")
#pragma GCC target("string"[,"string"]...)
```

6.5.8 Darwin Pragmas

The following pragmas are available for all architectures running the Darwin operating system. These are useful for compatibility with other macOS compilers.

`mark` *tokens*`...`
: This pragma is accepted, but has no effect.

`options align=`*alignment*
: This pragma sets the alignment of fields in structures. The values of *alignment* may be `mac68k`, to emulate m68k alignment, or `power`, to emulate PowerPC alignment. Uses of this pragma nest properly; to restore the previous setting, use `reset` for the *alignment*.

`segment` *tokens*`...`
: This pragma is accepted, but has no effect.

`unused (`*var* `[,` *var*`]...)`
: This pragma declares variables to be possibly unused. GCC does not produce warnings for the listed variables. The effect is similar to that of the `unused` attribute, except that this pragma may appear anywhere within the variables' scopes.

6.5.9 Solaris Pragmas

The Solaris target supports `#pragma redefine_extname` (see Section 6.5.10 [Symbol-Renaming Pragmas], page 740). It also supports additional `#pragma` directives for compatibility with the system compiler.

`align` *alignment* `(`*variable* `[,` *variable*`]...)`
: Increase the minimum alignment of each *variable* to *alignment*. This is the same as GCC's `aligned` attribute see Section 6.4.2 [Variable Attributes], page 699). Macro expansion occurs on the arguments to this pragma when compiling C and Objective-C. It does not currently occur when compiling C++, but this is a bug which may be fixed in a future release.

`fini (`*function* `[,` *function*`]...)`
: This pragma causes each listed *function* to be called after main, or during shared module unloading, by adding a call to the `.fini` section.

`init (`*function* `[,` *function*`]...)`
: This pragma causes each listed *function* to be called during initialization (before `main`) or during shared module loading, by adding a call to the `.init` section.

6.5.10 Symbol-Renaming Pragmas

GCC supports a `#pragma` directive that changes the name used in assembly for a given declaration. While this pragma is supported on all platforms, it is intended primarily to provide compatibility with the Solaris system headers. This effect can also be achieved using the asm labels extension (see Section 6.11.5 [Asm Labels], page 806).

`redefine_extname` *oldname newname*
: This pragma gives the C function *oldname* the assembly symbol *newname*. The preprocessor macro `__PRAGMA_REDEFINE_EXTNAME` is defined if this pragma is available (currently on all platforms).

This pragma and the `asm` labels extension interact in a complicated manner. Here are some corner cases you may want to be aware of:

1. This pragma silently applies only to declarations with external linkage. The `asm` label feature does not have this restriction.
2. In C++, this pragma silently applies only to declarations with "C" linkage. Again, `asm` labels do not have this restriction.
3. If either of the ways of changing the assembly name of a declaration are applied to a declaration whose assembly name has already been determined (either by a previous use of one of these features, or because the compiler needed the assembly name in order to generate code), and the new name is different, a warning issues and the name does not change.
4. The *oldname* used by `#pragma redefine_extname` is always the C-language name.

6.5.11 Structure-Layout Pragmas

For compatibility with Microsoft Windows compilers, GCC supports a set of `#pragma pack` directives that change the maximum alignment of members of structures (other than zero-width bit-fields), unions, and classes subsequently defined. The *n* value below specifies the new alignment in bytes and may have the value 1, 2, 4, 8, and 16. A value of 0 is also permitted and indicates the default alignment (as if no `#pragma pack` were in effect) should be used.

`#pragma pack(n)`
: Sets the new alignment according to *n*.

`#pragma pack()`
: Sets the alignment to the one that was in effect when compilation started (see also command-line option `-fpack-struct[=n]`. See Section 3.18 [Code Gen Options], page 315).

`#pragma pack(push[,n])`
: Pushes the current alignment setting on an internal stack and then optionally sets the new alignment.

`#pragma pack(pop)`
: Restores the alignment setting to the one saved at the top of the internal stack (and removes that stack entry). Note that `#pragma pack([n])` does not influence this internal stack; thus it is possible to have `#pragma pack(push)` followed by multiple `#pragma pack(n)` instances, with the original state restored by a single `#pragma pack(pop)`.

You can also use the `packed` type attribute (see Section 6.4.3.1 [Common Type Attributes], page 715) to pack a structure. However, the `packed` attribute interferes with `#pragma pack`, and attempting to use them together may cause spurious warnings or unexpected behavior.

Some targets, e.g. x86 and PowerPC, support the `#pragma ms_struct` directive, which causes subsequent structure and union declarations to be laid out in the same way as `__attribute__ ((ms_struct))`; see Section 6.4.2.15 [x86 Variable Attributes], page 714.

`#pragma ms_struct on`
: Turns on the Microsoft layout.

`#pragma ms_struct off`
: Turns off the Microsoft layout.

`#pragma ms_struct reset`
: Goes back to the default layout.

Most targets also support the `#pragma scalar_storage_order` directive which lays out subsequent structure and union declarations in in the same way as the documented `__attribute__ ((scalar_storage_order))`; see Section 6.4.3.1 [Common Type Attributes], page 715.

`#pragma scalar_storage_order big-endian`
`#pragma scalar_storage_order little-endian`
: Set the storage order of scalar fields to big- or little-endian, respectively.

`#pragma scalar_storage_order default`
: Goes back to the endianness that was in effect when compilation started (see also command-line option `-fsso-struct=endianness` see Section 3.4 [C Dialect Options], page 45).

6.5.12 Weak Pragmas

For compatibility with SVR4, GCC supports a set of `#pragma` directives for declaring symbols to be weak, and defining weak aliases.

`#pragma weak symbol`
: This pragma declares *symbol* to be weak, as if the declaration had the attribute of the same name. The pragma may appear before or after the declaration of *symbol*. It is not an error for *symbol* to never be defined at all.

`#pragma weak symbol1 = symbol2`
: This pragma declares *symbol1* to be a weak alias of *symbol2*. It is an error if *symbol2* is not defined in the current translation unit.

6.5.13 Diagnostic Pragmas

GCC allows the user to selectively enable or disable certain types of diagnostics, and change the kind of the diagnostic. For example, a project's policy might require that all sources compile with `-Werror` but certain files might have exceptions allowing specific types of warnings. Or, a project might selectively enable diagnostics and treat them as errors depending on which preprocessor macros are defined.

`#pragma GCC diagnostic kind option`
: Modifies the disposition of a diagnostic. Note that not all diagnostics are modifiable; at the moment only warnings (normally controlled by '`-W...`') can be controlled, and not all of them. Use `-fdiagnostics-show-option` to determine which diagnostics are controllable and which option controls them.

  kind is '`error`' to treat this diagnostic as an error, '`warning`' to treat it like a warning (even if `-Werror` is in effect), or '`ignored`' if the diagnostic is to be ignored. *option* is a double quoted string that matches the command-line option.

```
#pragma GCC diagnostic warning "-Wformat"
```

```
#pragma GCC diagnostic error "-Wformat"
#pragma GCC diagnostic ignored "-Wformat"
```

Note that these pragmas override any command-line options. GCC keeps track of the location of each pragma, and issues diagnostics according to the state as of that point in the source file. Thus, pragmas occurring after a line do not affect diagnostics caused by that line.

`#pragma GCC diagnostic push`
`#pragma GCC diagnostic pop`

Causes GCC to remember the state of the diagnostics as of each `push`, and restore to that point at each `pop`. If a `pop` has no matching `push`, the command-line options are restored.

```
#pragma GCC diagnostic error "-Wuninitialized"
  foo(a);                       /* error is given for this one */
#pragma GCC diagnostic push
#pragma GCC diagnostic ignored "-Wuninitialized"
  foo(b);                       /* no diagnostic for this one */
#pragma GCC diagnostic pop
  foo(c);                       /* error is given for this one */
#pragma GCC diagnostic pop
  foo(d);                       /* depends on command-line options */
```

`#pragma GCC diagnostic ignored_attributes`

Similarly to `-Wno-attributes=`, this pragma allows users to suppress warnings about unknown scoped attributes (in C++11 and C23). For example, `#pragma GCC diagnostic ignored_attributes "vendor::attr"` disables warning about the following declaration:

```
[[vendor::attr]] void f();
```

whereas `#pragma GCC diagnostic ignored_attributes "vendor::"` prevents warning about both of these declarations:

```
[[vendor::safe]] void f();
[[vendor::unsafe]] void f2();
```

GCC also offers a simple mechanism for printing messages during compilation.

`#pragma message` *`string`*

Prints *string* as a compiler message on compilation. The message is informational only, and is neither a compilation warning nor an error. Newlines can be included in the string by using the '`\n`' escape sequence.

```
#pragma message "Compiling " __FILE__ "..."
```

string may be parenthesized, and is printed with location information. For example,

```
#define DO_PRAGMA(x) _Pragma (#x)
#define TODO(x) DO_PRAGMA(message ("TODO - " #x))

TODO(Remember to fix this)
```

prints '`/tmp/file.c:4: note: #pragma message: TODO - Remember to fix this`'.

`#pragma GCC error` *`message`*

Generates an error message. This pragma *is* considered to indicate an error in the compilation, and it will be treated as such.

Newlines can be included in the string by using the '`\n`' escape sequence. They will be displayed as newlines even if the `-fmessage-length` option is set to zero.

The error is only generated if the pragma is present in the code after preprocessing has been completed. It does not matter however if the code containing the pragma is unreachable:

```
#if 0
#pragma GCC error "this error is not seen"
#endif
void foo (void)
{
  return;
#pragma GCC error "this error is seen"
}
```

`#pragma GCC warning` *message*
: This is just like '`pragma GCC error`' except that a warning message is issued instead of an error message. Unless `-Werror` is in effect, in which case this pragma will generate an error as well.

6.5.14 Visibility Pragmas

`#pragma GCC visibility push(`*visibility*`)`
`#pragma GCC visibility pop`
: This pragma allows the user to set the visibility for multiple declarations without having to give each a visibility attribute (see Section 6.4.1 [Function Attributes], page 621).

In C++, '`#pragma GCC visibility`' affects only namespace-scope declarations. Class members and template specializations are not affected; if you want to override the visibility for a particular member or instantiation, you must use an attribute.

6.5.15 Push/Pop Macro Pragmas

For compatibility with Microsoft Windows compilers, GCC supports '`#pragma push_macro("`*macro_name*`")`' and '`#pragma pop_macro("`*macro_name*`")`'.

`#pragma push_macro("`*macro_name*`")`
: This pragma saves the value of the macro named as *macro_name* to the top of the stack for this macro.

`#pragma pop_macro("`*macro_name*`")`
: This pragma sets the value of the macro named as *macro_name* to the value on top of the stack for this macro. If the stack for *macro_name* is empty, the value of the macro remains unchanged.

For example:

```
#define X  1
#pragma push_macro("X")
#undef X
#define X -1
#pragma pop_macro("X")
```

```
int x [X];
```

In this example, the definition of X as 1 is saved by `#pragma push_macro` and restored by `#pragma pop_macro`.

6.5.16 Function Specific Option Pragmas

`#pragma GCC target (`*string*`, ...)`
: This pragma allows you to set target-specific options for functions defined later in the source file. One or more strings can be specified. Each function that is defined after this point is treated as if it had been declared with one `target(`*string*`)` attribute for each *string* argument. The parentheses around the strings in the pragma are optional. See Section 6.4.1 [Function Attributes], page 621, for more information about the `target` attribute and the attribute syntax.

  The `#pragma GCC target` pragma is presently implemented for x86, ARM, AArch64, PowerPC, and S/390 targets only.

`#pragma GCC optimize (`*string*`, ...)`
: This pragma allows you to set global optimization options for functions defined later in the source file. One or more strings can be specified. Each function that is defined after this point is treated as if it had been declared with one `optimize(`*string*`)` attribute for each *string* argument. The parentheses around the strings in the pragma are optional. See Section 6.4.1 [Function Attributes], page 621, for more information about the `optimize` attribute and the attribute syntax.

`#pragma GCC push_options`
`#pragma GCC pop_options`
: These pragmas maintain a stack of the current target and optimization options. It is intended for include files where you temporarily want to switch to using a different '`#pragma GCC target`' or '`#pragma GCC optimize`' and then to pop back to the previous options.

`#pragma GCC reset_options`
: This pragma clears the current `#pragma GCC target` and `#pragma GCC optimize` to use the default switches as specified on the command line.

6.5.17 Loop-Specific Pragmas

`#pragma GCC ivdep`
: With this pragma, the programmer asserts that there are no loop-carried dependencies which would prevent consecutive iterations of the following loop from executing concurrently with SIMD (single instruction multiple data) instructions.

  For example, the compiler can only unconditionally vectorize the following loop with the pragma:

```
void foo (int n, int *a, int *b, int *c)
{
  int i, j;
#pragma GCC ivdep
```

```
  for (i = 0; i < n; ++i)
    a[i] = b[i] + c[i];
}
```

In this example, using the `restrict` qualifier had the same effect. In the following example, that would not be possible. Assume $k < -m$ or $k >= m$. Only with the pragma, the compiler knows that it can unconditionally vectorize the following loop:

```
void ignore_vec_dep (int *a, int k, int c, int m)
{
#pragma GCC ivdep
  for (int i = 0; i < m; i++)
    a[i] = a[i + k] * c;
}
```

`#pragma GCC novector`

With this pragma, the programmer asserts that the following loop should be prevented from executing concurrently with SIMD (single instruction multiple data) instructions.

For example, the compiler cannot vectorize the following loop with the pragma:

```
void foo (int n, int *a, int *b, int *c)
{
  int i, j;
#pragma GCC novector
  for (i = 0; i < n; ++i)
    a[i] = b[i] + c[i];
}
```

`#pragma GCC unroll n`

You can use this pragma to control how many times a loop should be unrolled. It must be placed immediately before a `for`, `while` or `do` loop or a `#pragma GCC ivdep`, and applies only to the loop that follows. *n* is an integer constant expression specifying the unrolling factor. The values of 0 and 1 block any unrolling of the loop.

If the loop is vectorized the vectorizer considers extra unrolling to honor the unroll factor. After vectorizing a loop the pragma is dropped. Whether the loop is unrolled or not will be determined by target costing. The resulting vectorized loop may still be unrolled more in later passes depending on the target costing.

6.6 Thread-Local Storage

Thread-local storage (TLS) is a mechanism by which variables are allocated such that there is one instance of the variable per extant thread. The runtime model GCC uses to implement this originates in the IA-64 processor-specific ABI, but has since been migrated to other processors as well. It requires significant support from the linker (`ld`), dynamic linker (`ld.so`), and system libraries (`libc.so` and `libpthread.so`), so it is not available everywhere.

At the user level, the extension is visible with a new storage class keyword: `__thread`. For example:

```
__thread int i;
extern __thread struct state s;
```

```
static __thread char *p;
```

The `__thread` specifier may be used alone, with the `extern` or `static` specifiers, but with no other storage class specifier. When used with `extern` or `static`, `__thread` must appear immediately after the other storage class specifier.

The `__thread` specifier may be applied to any global, file-scoped static, function-scoped static, or static data member of a class. It may not be applied to block-scoped automatic or non-static data member.

When the address-of operator is applied to a thread-local variable, it is evaluated at run time and returns the address of the current thread's instance of that variable. An address so obtained may be used by any thread. When a thread terminates, any pointers to thread-local variables in that thread become invalid.

No static initialization may refer to the address of a thread-local variable.

In C++, if an initializer is present for a thread-local variable, it must be a *constant-expression*, as defined in 5.19.2 of the ANSI/ISO C++ standard.

See ELF Handling For Thread-Local Storage (`https://www.akkadia.org/drepper/tls.pdf`) for a detailed explanation of the four thread-local storage addressing models, and how the runtime is expected to function.

6.6.1 ISO/IEC 9899:1999 Edits for Thread-Local Storage

The following are a set of changes to ISO/IEC 9899:1999 (aka C99) that document the exact semantics of the language extension.

- *5.1.2 Execution environments*

  Add new text after paragraph 1

  > Within either execution environment, a *thread* is a flow of control within a program. It is implementation defined whether or not there may be more than one thread associated with a program. It is implementation defined how threads beyond the first are created, the name and type of the function called at thread startup, and how threads may be terminated. However, objects with thread storage duration shall be initialized before thread startup.

- *6.2.4 Storage durations of objects*

  Add new text before paragraph 3

  > An object whose identifier is declared with the storage-class specifier `__thread` has *thread storage duration*. Its lifetime is the entire execution of the thread, and its stored value is initialized only once, prior to thread startup.

- *6.4.1 Keywords*

  Add `__thread`.

- *6.7.1 Storage-class specifiers*

  Add `__thread` to the list of storage class specifiers in paragraph 1.

  Change paragraph 2 to

  > With the exception of `__thread`, at most one storage-class specifier may be given [. . .]. The `__thread` specifier may be used alone, or immediately following `extern` or `static`.

Add new text after paragraph 6

> The declaration of an identifier for a variable that has block scope that specifies `__thread` shall also specify either `extern` or `static`.
>
> The `__thread` specifier shall be used only with variables.

6.6.2 ISO/IEC 14882:1998 Edits for Thread-Local Storage

The following are a set of changes to ISO/IEC 14882:1998 (aka C++98) that document the exact semantics of the language extension.

- **[intro.execution]**

  New text after paragraph 4

  > A *thread* is a flow of control within the abstract machine. It is implementation defined whether or not there may be more than one thread.

  New text after paragraph 7

  > It is unspecified whether additional action must be taken to ensure when and whether side effects are visible to other threads.

- **[lex.key]**

  Add `__thread`.

- **[basic.start.main]**

  Add after paragraph 5

  > The thread that begins execution at the `main` function is called the *main thread*. It is implementation defined how functions beginning threads other than the main thread are designated or typed. A function so designated, as well as the `main` function, is called a *thread startup function*. It is implementation defined what happens if a thread startup function returns. It is implementation defined what happens to other threads when any thread calls `exit`.

- **[basic.start.init]**

  Add after paragraph 4

  > The storage for an object of thread storage duration shall be statically initialized before the first statement of the thread startup function. An object of thread storage duration shall not require dynamic initialization.

- **[basic.start.term]**

  Add after paragraph 3

  > The type of an object with thread storage duration shall not have a non-trivial destructor, nor shall it be an array type whose elements (directly or indirectly) have non-trivial destructors.

- **[basic.stc]**

  Add "thread storage duration" to the list in paragraph 1.

  Change paragraph 2

  > Thread, static, and automatic storage durations are associated with objects introduced by declarations [. . .].

  Add `__thread` to the list of specifiers in paragraph 3.

- **[basic.stc.thread]**

  New section before **[basic.stc.static]**

  > The keyword `__thread` applied to a non-local object gives the object thread storage duration.
  >
  > A local variable or class data member declared both `static` and `__thread` gives the variable or member thread storage duration.

- **[basic.stc.static]**

  Change paragraph 1

  > All objects that have neither thread storage duration, dynamic storage duration nor are local [. . .].

- **[dcl.stc]**

  Add `__thread` to the list in paragraph 1.

  Change paragraph 1

  > With the exception of `__thread`, at most one *storage-class-specifier* shall appear in a given *decl-specifier-seq*. The `__thread` specifier may be used alone, or immediately following the `extern` or `static` specifiers. [. . .]

  Add after paragraph 5

  > The `__thread` specifier can be applied only to the names of objects and to anonymous unions.

- **[class.mem]**

  Add after paragraph 6

  > Non-`static` members shall not be `__thread`.

6.7 OpenMP

OpenMP (Open Multi-Processing) is an application programming interface (API) that supports multi-platform shared memory multiprocessing programming in C/C++ and Fortran on many architectures, including Unix and Microsoft Windows platforms. It consists of a set of compiler directives, library routines, and environment variables that influence run-time behavior.

GCC implements all of the OpenMP Application Program Interface v4.5 (`https://www.openmp.org/specifications/`), and many features from later versions of the OpenMP specification. See Section "OpenMP Implementation Status" in *GNU Offloading and Multi Processing Runtime Library*, for more details about currently supported OpenMP features.

To enable the processing of OpenMP directives '`#pragma omp`', '`[[omp::directive(...)]]`', '`[[omp::decl(...)]]`', and '`[[omp::sequence(...)]]`' in C and C++, GCC needs to be invoked with the `-fopenmp` option. This option also arranges for automatic linking of the OpenMP runtime library. See *GNU Offloading and Multi Processing Runtime Library*.

See Section 3.7 [OpenMP and OpenACC Options], page 86, for additional options useful with `-fopenmp`.

6.8 OpenACC

OpenACC is an application programming interface (API) that supports offloading of code to accelerator devices. It consists of a set of compiler directives, library routines, and environment variables that influence run-time behavior.

GCC strives to be compatible with the OpenACC Application Programming Interface v2.6 (`https://www.openacc.org/`).

To enable the processing of OpenACC directives '`#pragma acc`' in C and C++, GCC needs to be invoked with the `-fopenacc` option. This option also arranges for automatic linking of the OpenACC runtime library. See *GNU Offloading and Multi Processing Runtime Library*.

See Section 3.7 [OpenMP and OpenACC Options], page 86, for additional options useful with `-fopenacc`.

6.9 An Inline Function is As Fast As a Macro

By declaring a function inline, you can direct GCC to make calls to that function faster. One way GCC can achieve this is to integrate that function's code into the code for its callers. This makes execution faster by eliminating the function-call overhead; in addition, if any of the actual argument values are constant, their known values may permit simplifications at compile time so that not all of the inline function's code needs to be included. The effect on code size is less predictable; object code may be larger or smaller with function inlining, depending on the particular case. You can also direct GCC to try to integrate all "simple enough" functions into their callers with the option `-finline-functions`.

GCC implements three different semantics of declaring a function inline. One is available with `-std=gnu89` or `-fgnu89-inline` or when `gnu_inline` attribute is present on all inline declarations, another when `-std=c99`, `-std=gnu99` or an option for a later C version is used (without `-fgnu89-inline`), and the third is used when compiling C++.

To declare a function inline, use the `inline` keyword in its declaration, like this:

```
static inline int
inc (int *a)
{
  return (*a)++;
}
```

If you are writing a header file to be included in ISO C90 programs, write `__inline__` instead of `inline`. See Section 6.12.23 [Alternate Keywords], page 824.

The three types of inlining behave similarly in two important cases: when the `inline` keyword is used on a `static` function, like the example above, and when a function is first declared without using the `inline` keyword and then is defined with `inline`, like this:

```
extern int inc (int *a);
inline int
inc (int *a)
{
  return (*a)++;
}
```

In both of these common cases, the program behaves the same as if you had not used the `inline` keyword, except for its speed.

When a function is both inline and `static`, if all calls to the function are integrated into the caller, and the function's address is never used, then the function's own assembler code is never referenced. In this case, GCC does not actually output assembler code for the function, unless you specify the option -fkeep-inline-functions. If there is a nonintegrated call, then the function is compiled to assembler code as usual. The function must also be compiled as usual if the program refers to its address, because that cannot be inlined.

Note that certain usages in a function definition can make it unsuitable for inline substitution. Among these usages are: variadic functions, use of alloca, use of computed goto (see Section 6.12.3 [Labels as Values], page 815), use of nonlocal goto, use of nested functions, use of setjmp, use of __builtin_longjmp and use of __builtin_return or __builtin_apply_args. Using -Winline warns when a function marked inline could not be substituted, and gives the reason for the failure.

As required by ISO C++, GCC considers member functions defined within the body of a class to be marked inline even if they are not explicitly declared with the inline keyword. You can override this with -fno-default-inline; see Section 3.5 [Options Controlling C++ Dialect], page 52.

GCC does not inline any functions when not optimizing unless you specify the 'always_inline' attribute for the function, like this:

```
/* Prototype.  */
inline void foo (const char) __attribute__((always_inline));
```

The remainder of this section is specific to GNU C90 inlining.

When an inline function is not static, then the compiler must assume that there may be calls from other source files; since a global symbol can be defined only once in any program, the function must not be defined in the other source files, so the calls therein cannot be integrated. Therefore, a non-static inline function is always compiled on its own in the usual fashion.

If you specify both inline and extern in the function definition, then the definition is used only for inlining. In no case is the function compiled on its own, not even if you refer to its address explicitly. Such an address becomes an external reference, as if you had only declared the function, and had not defined it.

This combination of inline and extern has almost the effect of a macro. The way to use it is to put a function definition in a header file with these keywords, and put another copy of the definition (lacking inline and extern) in a library file. The definition in the header file causes most calls to the function to be inlined. If any uses of the function remain, they refer to the single copy in the library.

6.10 When is a Volatile Object Accessed?

C has the concept of volatile objects. These are normally accessed by pointers and used for accessing hardware or inter-thread communication. The standard encourages compilers to refrain from optimizations concerning accesses to volatile objects, but leaves it implementation defined as to what constitutes a volatile access. The minimum requirement is that at a sequence point all previous accesses to volatile objects have stabilized and no subsequent accesses have occurred. Thus an implementation is free to reorder and combine volatile accesses that occur between sequence points, but cannot do so for accesses across a sequence point. The use of volatile does not allow you to violate the restriction on updating objects multiple times between two sequence points.

Accesses to non-volatile objects are not ordered with respect to volatile accesses. You cannot use a volatile object as a memory barrier to order a sequence of writes to non-volatile memory. For instance:

```
int *ptr = something;
volatile int vobj;
*ptr = something;
vobj = 1;
```

Unless **ptr* and *vobj* can be aliased, it is not guaranteed that the write to **ptr* occurs by the time the update of *vobj* happens. If you need this guarantee, you must use a stronger memory barrier such as:

```
int *ptr = something;
volatile int vobj;
*ptr = something;
asm volatile ("" : : : "memory");
vobj = 1;
```

A scalar volatile object is read when it is accessed in a void context:

```
volatile int *src = somevalue;
*src;
```

Such expressions are rvalues, and GCC implements this as a read of the volatile object being pointed to.

Assignments are also expressions and have an rvalue. However when assigning to a scalar volatile, the volatile object is not reread, regardless of whether the assignment expression's rvalue is used or not. If the assignment's rvalue is used, the value is that assigned to the volatile object. For instance, there is no read of *vobj* in all the following cases:

```
int obj;
volatile int vobj;
vobj = something;
obj = vobj = something;
obj ? vobj = onething : vobj = anotherthing;
obj = (something, vobj = anotherthing);
```

If you need to read the volatile object after an assignment has occurred, you must use a separate expression with an intervening sequence point.

As bit-fields are not individually addressable, volatile bit-fields may be implicitly read when written to, or when adjacent bit-fields are accessed. Bit-field operations may be optimized such that adjacent bit-fields are only partially accessed, if they straddle a storage unit boundary. For these reasons it is unwise to use volatile bit-fields to access hardware.

6.11 How to Use Inline Assembly Language in C Code

The `asm` keyword allows you to embed assembler instructions within C code. GCC provides two forms of inline `asm` statements. A *basic* `asm` statement is one with no operands (see Section 6.11.1 [Basic Asm], page 753), while an *extended* `asm` statement (see Section 6.11.2 [Extended Asm], page 754) includes one or more operands. The extended form is preferred for mixing C and assembly language within a function and can be used at top level as well with certain restrictions.

You can also use the `asm` keyword to override the assembler name for a C symbol, or to place a C variable in a specific register.

6.11.1 Basic Asm — Assembler Instructions Without Operands

A basic `asm` statement has the following syntax:

```
asm asm-qualifiers ( AssemblerInstructions )
```

For the C language, the `asm` keyword is a GNU extension. When writing C code that can be compiled with `-ansi` and the `-std` options that select C dialects without GNU extensions, use `__asm__` instead of `asm` (see Section 6.12.23 [Alternate Keywords], page 824). For the C++ language, `asm` is a standard keyword, but `__asm__` can be used for code compiled with `-fno-asm`.

Qualifiers

`volatile` The optional `volatile` qualifier has no effect. All basic `asm` blocks are implicitly volatile. Basic `asm` statements outside of functions may not use any qualifiers.

`inline` If you use the `inline` qualifier, then for inlining purposes the size of the `asm` statement is taken as the smallest size possible (see Section 6.11.7 [Size of an asm], page 811).

Parameters

AssemblerInstructions

This is a literal string that specifies the assembler code. In C++ with `-std=gnu++11` or later, it can also be a constant expression inside parentheses (see Section 6.11.4 [Asm constexprs], page 806).

The string can contain any instructions recognized by the assembler, including directives. GCC does not parse the assembler instructions themselves and does not know what they mean or even whether they are valid assembler input.

You may place multiple assembler instructions together in a single `asm` string, separated by the characters normally used in assembly code for the system. A combination that works in most places is a newline to break the line, plus a tab character (written as '`\n\t`'). Some assemblers allow semicolons as a line separator. However, note that some assembler dialects use semicolons to start a comment.

Remarks

Using extended `asm` (see Section 6.11.2 [Extended Asm], page 754) typically produces smaller, safer, and more efficient code, and in most cases it is a better solution than basic `asm`. However, functions declared with the `naked` attribute require only basic `asm` (see Section 6.4.1 [Function Attributes], page 621).

Basic `asm` statements may be used both inside a C function or at file scope ("top-level"), where you can use this technique to emit assembler directives, define assembly language macros that can be invoked elsewhere in the file, or write entire functions in assembly language.

Safely accessing C data and calling functions from basic `asm` is more complex than it may appear. To access C data, it is better to use extended `asm`.

Do not expect a sequence of `asm` statements to remain perfectly consecutive after compilation. If certain instructions need to remain consecutive in the output, put them in a single multi-instruction `asm` statement. Note that GCC's optimizers can move `asm` statements relative to other code, including across jumps.

`asm` statements may not perform jumps into other `asm` statements. GCC does not know about these jumps, and therefore cannot take account of them when deciding how to optimize. Jumps from `asm` to C labels are only supported in extended `asm`.

Under certain circumstances, GCC may duplicate (or remove duplicates of) your assembly code when optimizing. This can lead to unexpected duplicate symbol errors during compilation if your assembly code defines symbols or labels.

Warning: The C standards do not specify semantics for `asm`, making it a potential source of incompatibilities between compilers. These incompatibilities may not produce compiler warnings/errors.

GCC does not parse basic `asm`'s *AssemblerInstructions*, which means there is no way to communicate to the compiler what is happening inside them. GCC has no visibility of symbols in the `asm` and may discard them as unreferenced. It also does not know about side effects of the assembler code, such as modifications to memory or registers. Unlike some compilers, GCC assumes that no changes to general purpose registers occur. This assumption may change in a future release.

To avoid complications from future changes to the semantics and the compatibility issues between compilers, consider replacing basic `asm` with extended `asm`. See How to convert from basic asm to extended asm (`https://gcc.gnu.org/wiki/ConvertBasicAsmToExtended`) for information about how to perform this conversion.

The compiler copies the assembler instructions in a basic `asm` verbatim to the assembly language output file, without processing dialects or any of the '`%`' operators that are available with extended `asm`. This results in minor differences between basic `asm` strings and extended `asm` templates. For example, to refer to registers you might use '`%eax`' in basic `asm` and '`%%eax`' in extended `asm`.

On targets such as x86 that support multiple assembler dialects, all basic `asm` blocks use the assembler dialect specified by the `-masm` command-line option (see Section 3.20.54 [x86 Options], page 534). Basic `asm` provides no mechanism to provide different assembler strings for different dialects.

For basic `asm` with non-empty assembler string GCC assumes the assembler block does not change any general purpose registers, but it may read or write any globally accessible variable.

Here is an example of basic `asm` for i386:

```
/* Note that this code will not compile with -masm=intel */
#define DebugBreak() asm("int $3")
```

6.11.2 Extended Asm - Assembler Instructions with C Expression Operands

With extended `asm` you can read and write C variables from assembler and perform jumps from assembler code to C labels. Extended `asm` syntax uses colons ('`:`') to delimit the operand parameters after the assembler template:

```
asm asm-qualifiers ( AssemblerTemplate
                 : OutputOperands
```

```
                    [ : InputOperands
                    [ : Clobbers ] ])

asm asm-qualifiers ( AssemblerTemplate
                      : OutputOperands
                      : InputOperands
                      : Clobbers
                      : GotoLabels)
```

where in the last form, *asm-qualifiers* contains `goto` (and in the first form, not).

The `asm` keyword is a GNU extension. When writing code that can be compiled with `-ansi` and the various `-std` options, use `__asm__` instead of `asm` (see Section 6.12.23 [Alternate Keywords], page 824).

Qualifiers

`volatile` The typical use of extended `asm` statements is to manipulate input values to produce output values. However, your `asm` statements may also produce side effects. If so, you may need to use the `volatile` qualifier to disable certain optimizations. See [Volatile], page 756.

`inline` If you use the `inline` qualifier, then for inlining purposes the size of the `asm` statement is taken as the smallest size possible (see Section 6.11.7 [Size of an asm], page 811).

`goto` This qualifier informs the compiler that the `asm` statement may perform a jump to one of the labels listed in the *GotoLabels*. See [GotoLabels], page 769.

Parameters

AssemblerTemplate
: This is a literal string that is the template for the assembler code. It is a combination of fixed text and tokens that refer to the input, output, and goto parameters. See [AssemblerTemplate], page 758.

OutputOperands
: A comma-separated list describing the C variables modified by the instructions in the *AssemblerTemplate*. An empty list is permitted. See [OutputOperands], page 760.

InputOperands
: A comma-separated list describing the C expressions read by the instructions in the *AssemblerTemplate*. An empty list is permitted. See [InputOperands], page 764.

Clobbers
: A comma-separated list of registers or other values changed by the *AssemblerTemplate*, beyond those listed as outputs. An empty list is permitted. See [Clobbers and Scratch Registers], page 766.

GotoLabels
: When you are using the `goto` form of `asm`, this section contains the list of all C labels to which the code in the *AssemblerTemplate* may jump. See [GotoLabels], page 769.

asm statements may not perform jumps into other asm statements, only to the listed *GotoLabels*. GCC's optimizers do not know about other jumps; therefore they cannot take account of them when deciding how to optimize.

The total number of input + output + goto operands is limited to 30.

Remarks

The asm statement allows you to include assembly instructions directly within C code. This may help you to maximize performance in time-sensitive code or to access assembly instructions that are not readily available to C programs.

Similarly to basic asm, extended asm statements may be used both inside a C function or at file scope ("top-level"), where you can use this technique to emit assembler directives, define assembly language macros that can be invoked elsewhere in the file, or write entire functions in assembly language. Extended asm statements outside of functions may not use any qualifiers, may not specify clobbers, may not use %, + or & modifiers in constraints and can only use constraints which don't allow using any register.

Functions declared with the naked attribute require basic asm (see Section 6.4.1 [Function Attributes], page 621).

While the uses of asm are many and varied, it may help to think of an asm statement as a series of low-level instructions that convert input parameters to output parameters. So a simple (if not particularly useful) example for i386 using asm might look like this:

```
int src = 1;
int dst;

asm ("mov %1, %0\n\t"
    "add $1, %0"
    : "=r" (dst)
    : "r" (src));

printf("%d\n", dst);
```

This code copies src to dst and add 1 to dst.

6.11.2.1 Volatile

GCC's optimizers sometimes discard asm statements if they determine there is no need for the output variables. Also, the optimizers may move code out of loops if they believe that the code will always return the same result (i.e. none of its input values change between calls). Using the volatile qualifier disables these optimizations. asm statements that have no output operands and asm goto statements, are implicitly volatile.

This i386 code demonstrates a case that does not use (or require) the volatile qualifier. If it is performing assertion checking, this code uses asm to perform the validation. Otherwise, dwRes is unreferenced by any code. As a result, the optimizers can discard the asm statement, which in turn removes the need for the entire DoCheck routine. By omitting the volatile qualifier when it isn't needed you allow the optimizers to produce the most efficient code possible.

```
void DoCheck(uint32_t dwSomeValue)
{
```

```
    uint32_t dwRes;

    // Assumes dwSomeValue is not zero.
    asm ("bsfl %1,%0"
      : "=r" (dwRes)
      : "r" (dwSomeValue)
      : "cc");

    assert(dwRes > 3);
}
```

The next example shows a case where the optimizers can recognize that the input (`dwSomeValue`) never changes during the execution of the function and can therefore move the `asm` outside the loop to produce more efficient code. Again, using the `volatile` qualifier disables this type of optimization.

```
void do_print(uint32_t dwSomeValue)
{
   uint32_t dwRes;

   for (uint32_t x=0; x < 5; x++)
   {
      // Assumes dwSomeValue is not zero.
      asm ("bsfl %1,%0"
        : "=r" (dwRes)
        : "r" (dwSomeValue)
        : "cc");

      printf("%u: %u %u\n", x, dwSomeValue, dwRes);
   }
}
```

The following example demonstrates a case where you need to use the `volatile` qualifier. It uses the x86 `rdtsc` instruction, which reads the computer's time-stamp counter. Without the `volatile` qualifier, the optimizers might assume that the `asm` block will always return the same value and therefore optimize away the second call.

```
uint64_t msr;

asm volatile ( "rdtsc\n\t"    // Returns the time in EDX:EAX.
        "shl $32, %%rdx\n\t"  // Shift the upper bits left.
        "or %%rdx, %0"        // 'Or' in the lower bits.
        : "=a" (msr)
        :
        : "rdx");

printf("msr: %llx\n", msr);

// Do other work...
```

```
// Reprint the timestamp
asm volatile ( "rdtsc\n\t"    // Returns the time in EDX:EAX.
        "shl $32, %%rdx\n\t"  // Shift the upper bits left.
        "or %%rdx, %0"        // 'Or' in the lower bits.
        : "=a" (msr)
        :
        : "rdx");

printf("msr: %llx\n", msr);
```

GCC's optimizers do not treat this code like the non-volatile code in the earlier examples. They do not move it out of loops or omit it on the assumption that the result from a previous call is still valid.

Note that the compiler can move even `volatile asm` instructions relative to other code, including across jump instructions. For example, on many targets there is a system register that controls the rounding mode of floating-point operations. Setting it with a `volatile asm` statement, as in the following PowerPC example, does not work reliably.

```
asm volatile("mtfsf 255, %0" : : "f" (fpenv));
sum = x + y;
```

The compiler may move the addition back before the `volatile asm` statement. To make it work as expected, add an artificial dependency to the `asm` by referencing a variable in the subsequent code, for example:

```
asm volatile ("mtfsf 255,%1" : "=X" (sum) : "f" (fpenv));
sum = x + y;
```

Under certain circumstances, GCC may duplicate (or remove duplicates of) your assembly code when optimizing. This can lead to unexpected duplicate symbol errors during compilation if your `asm` code defines symbols or labels. Using '`%=`' (see [AssemblerTemplate], page 758) may help resolve this problem.

6.11.2.2 Assembler Template

An assembler template is a literal string containing assembler instructions. In C++ with `-std=gnu++11` or later, the assembler template can also be a constant expression inside parentheses (see Section 6.11.4 [Asm constexprs], page 806).

The compiler replaces tokens in the template that refer to inputs, outputs, and goto labels, and then outputs the resulting string to the assembler. The string can contain any instructions recognized by the assembler, including directives. GCC does not parse the assembler instructions themselves and does not know what they mean or even whether they are valid assembler input. However, it does count the statements (see Section 6.11.7 [Size of an asm], page 811).

You may place multiple assembler instructions together in a single `asm` string, separated by the characters normally used in assembly code for the system. A combination that works in most places is a newline to break the line, plus a tab character to move to the instruction field (written as '`\n\t`'). Some assemblers allow semicolons as a line separator. However, note that some assembler dialects use semicolons to start a comment.

Do not expect a sequence of `asm` statements to remain perfectly consecutive after compilation, even when you are using the `volatile` qualifier. If certain instructions need to remain consecutive in the output, put them in a single multi-instruction `asm` statement.

Accessing data from C programs without using input/output operands (such as by using global symbols directly from the assembler template) may not work as expected. Similarly, calling functions directly from an assembler template requires a detailed understanding of the target assembler and ABI.

Since GCC does not parse the assembler template, it has no visibility of any symbols it references. This may result in GCC discarding those symbols as unreferenced unless they are also listed as input, output, or goto operands.

Special format strings

In addition to the tokens described by the input, output, and goto operands, these tokens have special meanings in the assembler template:

'`%%`' Outputs a single '`%`' into the assembler code.

'`%=`' Outputs a number that is unique to each instance of the `asm` statement in the entire compilation. This option is useful when creating local labels and referring to them multiple times in a single template that generates multiple assembler instructions.

'`%{`'
'`%|`'
'`%}`' Outputs '`{`', '`|`', and '`}`' characters (respectively) into the assembler code. When unescaped, these characters have special meaning to indicate multiple assembler dialects, as described below.

Multiple assembler dialects in `asm` templates

On targets such as x86, GCC supports multiple assembler dialects. The `-masm` option controls which dialect GCC uses as its default for inline assembler. The target-specific documentation for the `-masm` option contains the list of supported dialects, as well as the default dialect if the option is not specified. This information may be important to understand, since assembler code that works correctly when compiled using one dialect will likely fail if compiled using another. See Section 3.20.54 [x86 Options], page 534.

If your code needs to support multiple assembler dialects (for example, if you are writing public headers that need to support a variety of compilation options), use constructs of this form:

```
{ dialect0 | dialect1 | dialect2... }
```

This construct outputs `dialect0` when using dialect #0 to compile the code, `dialect1` for dialect #1, etc. If there are fewer alternatives within the braces than the number of dialects the compiler supports, the construct outputs nothing.

For example, if an x86 compiler supports two dialects ('`att`', '`intel`'), an assembler template such as this:

```
"bt{l %[Offset],%[Base] | %[Base],%[Offset]}; jc %l2"
```

is equivalent to one of

```
"btl %[Offset],%[Base] ; jc %l2"    /* att dialect */
```

```
"bt %[Base],%[Offset]; jc %l2"       /* intel dialect */
```

Using that same compiler, this code:

```
"xchg{l}\t{%%}ebx, %1"
```

corresponds to either

```
"xchgl\t%%ebx, %1"                   /* att dialect */
"xchg\tebx, %1"                      /* intel dialect */
```

There is no support for nesting dialect alternatives.

6.11.2.3 Output Operands

An `asm` statement has zero or more output operands indicating the names of C variables modified by the assembler code.

In this i386 example, `old` (referred to in the template string as `%0`) and `*Base` (as `%1`) are outputs and `Offset` (`%2`) is an input:

```
bool old;

__asm__ ("btsl %2,%1\n\t" // Turn on zero-based bit #Offset in Base.
         "sbb %0,%0"      // Use the CF to calculate old.
   : "=r" (old), "+rm" (*Base)
   : "Ir" (Offset)
   : "cc");

return old;
```

Operands are separated by commas. Each operand has this format:

[`[`*asmSymbolicName*`]`] *constraint* (*cvariablename*)

asmSymbolicName
: Specifies an optional symbolic name for the operand. The literal square brackets '`[]`' around the *asmSymbolicName* are required both in the operand specification and references to the operand in the assembler template, i.e. '`%[Value]`'. The scope of the name is the `asm` statement that contains the definition. Any valid C identifier is acceptable, including names already defined in the surrounding code. No two operands within the same `asm` statement can use the same symbolic name.

  When not using an *asmSymbolicName*, use the (zero-based) position of the operand in the list of operands in the assembler template. For example if there are three output operands, use '`%0`' in the template to refer to the first, '`%1`' for the second, and '`%2`' for the third.

constraint
: A string constant specifying constraints on the placement of the operand; See Section 6.11.3 [Constraints], page 776, for details. In C++ with `-std=gnu++11` or later, the constraint can also be a constant expression inside parentheses (see Section 6.11.4 [Asm constexprs], page 806).

  Output constraints must begin with either '`=`' (a variable overwriting an existing value) or '`+`' (when reading and writing). When using '`=`', do not assume the location contains the existing value on entry to the `asm`, except when the operand is tied to an input; see [Input Operands], page 764.

After the prefix, there must be one or more additional constraints (see Section 6.11.3 [Constraints], page 776) that describe where the value resides. Common constraints include 'r' for register and 'm' for memory. When you list more than one possible location (for example, "=rm"), the compiler chooses the most efficient one based on the current context. If you list as many alternates as the asm statement allows, you permit the optimizers to produce the best possible code. If you must use a specific register, but your Machine Constraints do not provide sufficient control to select the specific register you want, local register variables may provide a solution (see Section 6.11.6.2 [Local Register Variables], page 808).

cvariablename

Specifies a C lvalue expression to hold the output, typically a variable name. The enclosing parentheses are a required part of the syntax.

When the compiler selects the registers to use to represent the output operands, it does not use any of the clobbered registers (see [Clobbers and Scratch Registers], page 766).

Output operand expressions must be lvalues. The compiler cannot check whether the operands have data types that are reasonable for the instruction being executed. For output expressions that are not directly addressable (for example a bit-field), the constraint must allow a register. In that case, GCC uses the register as the output of the asm, and then stores that register into the output.

Operands using the '+' constraint modifier count as two operands (that is, both as input and output) towards the total maximum of 30 operands per asm statement.

Use the '&' constraint modifier (see Section 6.11.3.3 [Modifiers], page 779) on all output operands that must not overlap an input. Otherwise, GCC may allocate the output operand in the same register as an unrelated input operand, on the assumption that the assembler code consumes its inputs before producing outputs. This assumption may be false if the assembler code actually consists of more than one instruction.

The same problem can occur if one output parameter (*a*) allows a register constraint and another output parameter (*b*) allows a memory constraint. The code generated by GCC to access the memory address in *b* can contain registers which *might* be shared by *a*, and GCC considers those registers to be inputs to the asm. As above, GCC assumes that such input registers are consumed before any outputs are written. This assumption may result in incorrect behavior if the asm statement writes to *a* before using *b*. Combining the '&' modifier with the register constraint on *a* ensures that modifying *a* does not affect the address referenced by *b*. Otherwise, the location of *b* is undefined if *a* is modified before using *b*.

asm supports operand modifiers on operands (for example '%k2' instead of simply '%2'). [GenericOperandmodifiers], page 771, lists the modifiers that are available on all targets. Other modifiers are hardware dependent. For example, the list of supported modifiers for x86 is found at [x86Operandmodifiers], page 771.

If the C code that follows the asm makes no use of any of the output operands, use volatile for the asm statement to prevent the optimizers from discarding the asm statement as unneeded (see [Volatile], page 756).

This code makes no use of the optional *asmSymbolicName*. Therefore it references the first output operand as %0 (were there a second, it would be %1, etc). The number of the first input operand is one greater than that of the last output operand. In this i386 example, that makes `Mask` referenced as `%1`:

```
uint32_t Mask = 1234;
uint32_t Index;

  asm ("bsfl %1, %0"
     : "=r" (Index)
     : "r" (Mask)
     : "cc");
```

That code overwrites the variable `Index` (‘`=`’), placing the value in a register (‘`r`’). Using the generic ‘`r`’ constraint instead of a constraint for a specific register allows the compiler to pick the register to use, which can result in more efficient code. This may not be possible if an assembler instruction requires a specific register.

The following i386 example uses the *asmSymbolicName* syntax. It produces the same result as the code above, but some may consider it more readable or more maintainable since reordering index numbers is not necessary when adding or removing operands. The names `aIndex` and `aMask` are only used in this example to emphasize which names get used where. It is acceptable to reuse the names `Index` and `Mask`.

```
uint32_t Mask = 1234;
uint32_t Index;

  asm ("bsfl %[aMask], %[aIndex]"
     : [aIndex] "=r" (Index)
     : [aMask] "r" (Mask)
     : "cc");
```

Here are some more examples of output operands.

```
uint32_t c = 1;
uint32_t d;
uint32_t *e = &c;

asm ("mov %[e], %[d]"
   : [d] "=rm" (d)
   : [e] "rm" (*e));
```

Here, `d` may either be in a register or in memory. Since the compiler might already have the current value of the `uint32_t` location pointed to by `e` in a register, you can enable it to choose the best location for `d` by specifying both constraints.

6.11.2.4 Flag Output Operands

Some targets have a special register that holds the “flags” for the result of an operation or comparison. Normally, the contents of that register are either unmodified by the asm, or the `asm` statement is considered to clobber the contents.

On some targets, a special form of output operand exists by which conditions in the flags register may be outputs of the asm. The set of conditions supported are target specific, but the general rule is that the output variable must be a scalar integer, and the value is boolean. When supported, the target defines the preprocessor symbol `__GCC_ASM_FLAG_OUTPUTS__`.

Because of the special nature of the flag output operands, the constraint may not include alternatives.

Most often, the target has only one flags register, and thus is an implied operand of many instructions. In this case, the operand should not be referenced within the assembler template via `%0` etc, as there's no corresponding text in the assembly language.

ARM
AArch64
: The flag output constraints for the ARM family are of the form '`=@cc`*cond*' where *cond* is one of the standard conditions defined in the ARM ARM for `ConditionHolds`.

  `eq` Z flag set, or equal

  `ne` Z flag clear or not equal

  `cs`
  `hs` C flag set or unsigned greater than equal

  `cc`
  `lo` C flag clear or unsigned less than

  `mi` N flag set or "minus"

  `pl` N flag clear or "plus"

  `vs` V flag set or signed overflow

  `vc` V flag clear

  `hi` unsigned greater than

  `ls` unsigned less than equal

  `ge` signed greater than equal

  `lt` signed less than

  `gt` signed greater than

  `le` signed less than equal

  The flag output constraints are not supported in thumb1 mode.

x86 family
: The flag output constraints for the x86 family are of the form '`=@cc`*cond*' where *cond* is one of the standard conditions defined in the ISA manual for `j`*cc* or `set`*cc*.

  `a` "above" or unsigned greater than

  `ae` "above or equal" or unsigned greater than or equal

  `b` "below" or unsigned less than

  `be` "below or equal" or unsigned less than or equal

  `c` carry flag set

  `e`
  `z` "equal" or zero flag set

`g` signed greater than

`ge` signed greater than or equal

`l` signed less than

`le` signed less than or equal

`o` overflow flag set

`p` parity flag set

`s` sign flag set

`na`
`nae`
`nb`
`nbe`
`nc`
`ne`
`ng`
`nge`
`nl`
`nle`
`no`
`np`
`ns`
`nz` "not" *flag*, or inverted versions of those above

s390 The flag output constraint for s390 is '`=@cc`'. Only one such constraint is allowed. The variable has to be stored in a '`int`' variable.

6.11.2.5 Input Operands

Input operands make values from C variables and expressions available to the assembly code.

Operands are separated by commas. Each operand has this format:

[`[`*asmSymbolicName*`]`] *constraint* `(`*cexpression*`)`

asmSymbolicName

Specifies an optional symbolic name for the operand. The literal square brackets '`[]`' around the *asmSymbolicName* are required both in the operand specification and references to the operand in the assembler template, i.e. '`%[Value]`'. The scope of the name is the `asm` statement that contains the definition. Any valid C identifier is acceptable, including names already defined in the surrounding code. No two operands within the same `asm` statement can use the same symbolic name.

When not using an *asmSymbolicName*, use the (zero-based) position of the operand in the list of operands in the assembler template. For example if there are two output operands and three inputs, use '`%2`' in the template to refer to the first input operand, '`%3`' for the second, and '`%4`' for the third.

constraint A string constant specifying constraints on the placement of the operand; See Section 6.11.3 [Constraints], page 776, for details. In C++ with `-std=gnu++11` or later, the constraint can also be a constant expression inside parentheses (see Section 6.11.4 [Asm constexprs], page 806).

Input constraint strings may not begin with either '`=`' or '`+`'. When you list more than one possible location (for example, '`"irm"`'), the compiler chooses the most efficient one based on the current context. If you must use a specific register, but your Machine Constraints do not provide sufficient control to select the specific register you want, local register variables may provide a solution (see Section 6.11.6.2 [Local Register Variables], page 808).

Input constraints can also be digits (for example, `"0"`). This indicates that the specified input must be in the same place as the output constraint at the (zero-based) index in the output constraint list. When using *asmSymbolicName* syntax for the output operands, you may use these names (enclosed in brackets '`[]`') instead of digits.

cexpression

This is the C variable or expression being passed to the `asm` statement as input. The enclosing parentheses are a required part of the syntax.

When the compiler selects the registers to use to represent the input operands, it does not use any of the clobbered registers (see [Clobbers and Scratch Registers], page 766).

If there are no output operands but there are input operands, place two consecutive colons where the output operands would go:

```
__asm__ ("some instructions"
   : /* No outputs. */
   : "r" (Offset / 8));
```

Warning: Do *not* modify the contents of input-only operands (except for inputs tied to outputs). The compiler assumes that on exit from the `asm` statement these operands contain the same values as they had before executing the statement. It is *not* possible to use clobbers to inform the compiler that the values in these inputs are changing. One common work-around is to tie the changing input variable to an output variable that never gets used. Note, however, that if the code that follows the `asm` statement makes no use of any of the output operands, the GCC optimizers may discard the `asm` statement as unneeded (see [Volatile], page 756).

`asm` supports operand modifiers on operands (for example '`%k2`' instead of simply '`%2`'). [GenericOperandmodifiers], page 771, lists the modifiers that are available on all targets. Other modifiers are hardware dependent. For example, the list of supported modifiers for x86 is found at [x86Operandmodifiers], page 771.

In this example using the fictitious `combine` instruction, the constraint `"0"` for input operand 1 says that it must occupy the same location as output operand 0. Only input operands may use numbers in constraints, and they must each refer to an output operand. Only a number (or the symbolic assembler name) in the constraint can guarantee that one operand is in the same place as another. The mere fact that `foo` is the value of both operands is not enough to guarantee that they are in the same place in the generated assembler code.

```
asm ("combine %2, %0"
```

```
        : "=r" (foo)
        : "0" (foo), "g" (bar));
```

Here is an example using symbolic names.

```
asm ("cmoveq %1, %2, %[result]"
    : [result] "=r"(result)
    : "r" (test), "r" (new), "[result]" (old));
```

6.11.2.6 Clobbers and Scratch Registers

While the compiler is aware of changes to entries listed in the output operands, the inline `asm` code may modify more than just the outputs. For example, calculations may require additional registers, or the processor may overwrite a register as a side effect of a particular assembler instruction. In order to inform the compiler of these changes, list them in the clobber list. Clobber list items are either register names or the special clobbers (listed below). Each clobber list item is a string constant enclosed in double quotes and separated by commas. In C++ with `-std=gnu++11` or later, a clobber list item can also be a constant expression inside parentheses (see Section 6.11.4 [Asm constexprs], page 806).

Clobber descriptions may not in any way overlap with an input or output operand. For example, you may not have an operand describing a register class with one member when listing that register in the clobber list. Variables declared to live in specific registers (see Section 6.11.6 [Explicit Register Variables], page 807) and used as `asm` input or output operands must have no part mentioned in the clobber description. In particular, there is no way to specify that input operands get modified without also specifying them as output operands.

When the compiler selects which registers to use to represent input and output operands, it does not use any of the clobbered registers. As a result, clobbered registers are available for any use in the assembler code.

Another restriction is that the clobber list should not contain the stack pointer register. This is because the compiler requires the value of the stack pointer to be the same after an `asm` statement as it was on entry to the statement. However, previous versions of GCC did not enforce this rule and allowed the stack pointer to appear in the list, with unclear semantics. This behavior is deprecated and listing the stack pointer may become an error in future versions of GCC.

Here is a realistic example for the VAX showing the use of clobbered registers:

```
asm volatile ("movc3 %0, %1, %2"
                : /* No outputs. */
                : "g" (from), "g" (to), "g" (count)
                : "r0", "r1", "r2", "r3", "r4", "r5", "memory");
```

Also, there are three special clobber arguments:

`"cc"` The `"cc"` clobber indicates that the assembler code modifies the flags register. On some machines, GCC represents the condition codes as a specific hardware register; `"cc"` serves to name this register. On other machines, condition code handling is different, and specifying `"cc"` has no effect. But it is valid no matter what the target.

"memory" The "memory" clobber tells the compiler that the assembly code performs memory reads or writes to items other than those listed in the input and output operands (for example, accessing the memory pointed to by one of the input parameters). To ensure memory contains correct values, GCC may need to flush specific register values to memory before executing the asm. Further, the compiler does not assume that any values read from memory before an asm remain unchanged after that asm; it reloads them as needed. Using the "memory" clobber effectively forms a read/write memory barrier for the compiler.

Note that this clobber does not prevent the *processor* from doing speculative reads past the asm statement. To prevent that, you need processor-specific fence instructions.

"redzone"

The "redzone" clobber tells the compiler that the assembly code may write to the stack red zone, area below the stack pointer which on some architectures in some calling conventions is guaranteed not to be changed by signal handlers, interrupts or exceptions and so the compiler can store there temporaries in leaf functions. On targets which have no concept of the stack red zone, the clobber is ignored. It should be used e.g. in case the assembly code uses call instructions or pushes something to the stack without taking the red zone into account by subtracting red zone size from the stack pointer first and restoring it afterwards.

Flushing registers to memory has performance implications and may be an issue for time-sensitive code. You can provide better information to GCC to avoid this, as shown in the following examples. At a minimum, aliasing rules allow GCC to know what memory *doesn't* need to be flushed.

Here is a fictitious sum of squares instruction, that takes two pointers to floating point values in memory and produces a floating point register output. Notice that x, and y both appear twice in the asm parameters, once to specify memory accessed, and once to specify a base register used by the asm. You won't normally be wasting a register by doing this as GCC can use the same register for both purposes. However, it would be foolish to use both %1 and %3 for x in this asm and expect them to be the same. In fact, %3 may well not be a register. It might be a symbolic memory reference to the object pointed to by x.

```
asm ("sumsq %0, %1, %2"
     : "+f" (result)
     : "r" (x), "r" (y), "m" (*x), "m" (*y));
```

Here is a fictitious *z++ = *x++ * *y++ instruction. Notice that the x, y and z pointer registers must be specified as input/output because the asm modifies them.

```
asm ("vecmul %0, %1, %2"
     : "+r" (z), "+r" (x), "+r" (y), "=m" (*z)
     : "m" (*x), "m" (*y));
```

An x86 example where the string memory argument is of unknown length.

```
asm("repne scasb"
    : "=c" (count), "+D" (p)
    : "m" (*(const char (*)[]) p), "0" (-1), "a" (0));
```

If you know the above will only be reading a ten byte array then you could instead use a memory input like: "m" (*(const char (*)[10]) p).

Here is an example of a PowerPC vector scale implemented in assembly, complete with vector and condition code clobbers, and some initialized offset registers that are unchanged by the `asm`.

```
void
dscal (size_t n, double *x, double alpha)
{
  asm ("/* lots of asm here */"
       : "+m" (*(double (*)[n]) x), "+&r" (n), "+b" (x)
       : "d" (alpha), "b" (32), "b" (48), "b" (64),
         "b" (80), "b" (96), "b" (112)
       : "cr0",
         "vs32","vs33","vs34","vs35","vs36","vs37","vs38","vs39",
         "vs40","vs41","vs42","vs43","vs44","vs45","vs46","vs47");
}
```

Rather than allocating fixed registers via clobbers to provide scratch registers for an `asm` statement, an alternative is to define a variable and make it an early-clobber output as with `a2` and `a3` in the example below. This gives the compiler register allocator more freedom. You can also define a variable and make it an output tied to an input as with `a0` and `a1`, tied respectively to `ap` and `lda`. Of course, with tied outputs your `asm` can't use the input value after modifying the output register since they are one and the same register. What's more, if you omit the early-clobber on the output, it is possible that GCC might allocate the same register to another of the inputs if GCC could prove they had the same value on entry to the `asm`. This is why `a1` has an early-clobber. Its tied input, `lda` might conceivably be known to have the value 16 and without an early-clobber share the same register as `%11`. On the other hand, `ap` can't be the same as any of the other inputs, so an early-clobber on `a0` is not needed. It is also not desirable in this case. An early-clobber on `a0` would cause GCC to allocate a separate register for the `"m" (*(const double (*)[]) ap)` input. Note that tying an input to an output is the way to set up an initialized temporary register modified by an `asm` statement. An input not tied to an output is assumed by GCC to be unchanged, for example `"b" (16)` below sets up `%11` to 16, and GCC might use that register in following code if the value 16 happened to be needed. You can even use a normal `asm` output for a scratch if all inputs that might share the same register are consumed before the scratch is used. The VSX registers clobbered by the `asm` statement could have used this technique except for GCC's limit on the number of `asm` parameters.

```
static void
dgemv_kernel_4x4 (long n, const double *ap, long lda,
                  const double *x, double *y, double alpha)
{
  double *a0;
  double *a1;
  double *a2;
  double *a3;

  __asm__
    (
     /* lots of asm here */
     "#n=%1 ap=%8=%12 lda=%13 x=%7=%10 y=%0=%2 alpha=%9 o16=%11\n"
     "#a0=%3 a1=%4 a2=%5 a3=%6"
     :
       "+m" (*(double (*)[n]) y),
       "+&r" (n), // 1
       "+b" (y), // 2
```

```
          "=b" (a0), // 3
          "=&b" (a1), // 4
          "=&b" (a2), // 5
          "=&b" (a3) // 6
        :
          "m" (*(const double (*)[n]) x),
          "m" (*(const double (*)[]) ap),
          "d" (alpha), // 9
          "r" (x), // 10
          "b" (16), // 11
          "3" (ap), // 12
          "4" (lda) // 13
        :
          "cr0",
          "vs32","vs33","vs34","vs35","vs36","vs37",
          "vs40","vs41","vs42","vs43","vs44","vs45","vs46","vs47"
        );
    }
```

6.11.2.7 Goto Labels

`asm goto` allows assembly code to jump to one or more C labels. The *GotoLabels* section in an `asm goto` statement contains a comma-separated list of all C labels to which the assembler code may jump. GCC assumes that `asm` execution falls through to the next statement (if this is not the case, consider using the `__builtin_unreachable` intrinsic after the `asm` statement). Optimization of `asm goto` may be improved by using the `hot` and `cold` label attributes (see Section 6.4.4 [Label Attributes], page 730).

If the assembler code does modify anything, use the `"memory"` clobber to force the optimizers to flush all register values to memory and reload them if necessary after the `asm` statement.

Also note that an `asm goto` statement is always implicitly considered volatile.

Be careful when you set output operands inside `asm goto` only on some possible control flow paths. If you don't set up the output on given path and never use it on this path, it is okay. Otherwise, you should use '`+`' constraint modifier meaning that the operand is input and output one. With this modifier you will have the correct values on all possible paths from the `asm goto`.

To reference a label in the assembler template, prefix it with '`%l`' (lowercase '`L`') followed by its (zero-based) position in *GotoLabels* plus the number of input and output operands. Output operand with constraint modifier '`+`' is counted as two operands because it is considered as one output and one input operand. For example, if the `asm` has three inputs, one output operand with constraint modifier '`+`' and one output operand with constraint modifier '`=`' and references two labels, refer to the first label as '`%l6`' and the second as '`%l7`').

Alternately, you can reference labels using the actual C label name enclosed in brackets. For example, to reference a label named `carry`, you can use '`%l[carry]`'. The label must still be listed in the *GotoLabels* section when using this approach. It is better to use the named references for labels as in this case you can avoid counting input and output operands and special treatment of output operands with constraint modifier '`+`'.

Here is an example of `asm goto` for i386:

```
asm goto (
```

```
        "btl %1, %0\n\t"
        "jc %l2"
        : /* No outputs. */
        : "r" (p1), "r" (p2)
        : "cc"
        : carry);

    return 0;

    carry:
    return 1;
```

The following example shows an `asm goto` that uses a memory clobber.

```
int frob(int x)
{
  int y;
  asm goto ("frob %%r5, %1; jc %l[error]; mov (%2), %%r5"
            : /* No outputs. */
            : "r"(x), "r"(&y)
            : "r5", "memory"
            : error);
  return y;
error:
  return -1;
}
```

The following example shows an `asm goto` that uses an output.

```
int foo(int count)
{
  asm goto ("dec %0; jb %l[stop]"
            : "+r" (count)
            :
            :
            : stop);
  return count;
stop:
  return 0;
}
```

The following artificial example shows an `asm goto` that sets up an output only on one path inside the `asm goto`. Usage of constraint modifier '`=`' instead of '`+`' would be wrong as `factor` is used on all paths from the `asm goto`.

```
int foo(int inp)
{
  int factor = 0;
  asm goto ("cmp %1, 10; jb %l[lab]; mov 2, %0"
            : "+r" (factor)
            : "r" (inp)
```

```
            :
            : lab);
lab:
  return inp * factor; /* return 2 * inp or 0 if inp < 10 */
}
```

6.11.2.8 Generic Operand Modifiers

The following table shows the modifiers supported by all targets and their effects:

Modifier	Description	Example
c	Require a constant operand and print the constant expression with no punctuation.	%c0
cc	Like '%c' except try harder to print it with no punctuation. '%c' can e.g. fail to print constant addresses in position independent code on some architectures.	%cc0
n	Like '%c' except that the value of the constant is negated before printing.	%n0
a	Substitute a memory reference, with the actual operand treated as the address. This may be useful when outputting a "load address" instruction, because often the assembler syntax for such an instruction requires you to write the operand as if it were a memory reference.	%a0
l	Print the label name with no punctuation.	%l0

6.11.2.9 AArch64 Operand Modifiers

The following table shows the modifiers supported by AArch64 and their effects:

Modifier	Description
w	Print a 32-bit general-purpose register name or, given a constant zero operand, the 32-bit zero register (wzr).
x	Print a 64-bit general-purpose register name or, given a constant zero operand, the 64-bit zero register (xzr).
b	Print an FP/SIMD register name with a b (byte, 8-bit) prefix.
h	Print an FP/SIMD register name with an h (halfword, 16-bit) prefix.
s	Print an FP/SIMD register name with an s (single word, 32-bit) prefix.
d	Print an FP/SIMD register name with a d (doubleword, 64-bit) prefix.
q	Print an FP/SIMD register name with a q (quadword, 128-bit) prefix.
Z	Print an FP/SIMD register name as an SVE register (i.e. with a z prefix). This is a no-op for SVE register operands.

6.11.2.10 x86 Operand Modifiers

References to input, output, and goto operands in the assembler template of extended asm statements can use modifiers to affect the way the operands are formatted in the code output to the assembler. For example, the following code uses the 'h' and 'b' modifiers for x86:

```
uint16_t  num;
asm volatile ("xchg %h0, %b0" : "+a" (num) );
```

These modifiers generate this assembler code:

```
xchg %ah, %al
```

The rest of this discussion uses the following code for illustrative purposes.

```
int main()
{
   int iInt = 1;

top:

   asm volatile goto ("some assembler instructions here"
   : /* No outputs. */
   : "q" (iInt), "X" (sizeof(unsigned char) + 1), "i" (42)
   : /* No clobbers. */
   : top);
}
```

With no modifiers, this is what the output from the operands would be for the '`att`' and '`intel`' dialects of assembler:

Operand	'`att`'	'`intel`'
`%0`	`%eax`	`eax`
`%1`	`$2`	`2`
`%3`	`$.L3`	`OFFSET FLAT:.L3`

The table below shows the list of supported modifiers and their effects.

Modifier	**Description**	**Operand**	'`att`'	'`intel`'
`A`	Print an absolute memory reference.	`%A0`	`*%rax`	`rax`
`b`	Print the QImode name of the register.	`%b0`	`%al`	`al`
`c`	Require a constant operand and print the constant expression with no punctuation.	`%c1`	`2`	`2`
`E`	Print the address in Double Integer (DImode) mode (8 bytes) when the target is 64-bit. Otherwise mode is unspecified (VOIDmode).	`%E1`	`%(rax)`	`[rax]`
`h`	Print the QImode name for a "high" register.	`%h0`	`%ah`	`ah`
`H`	Add 8 bytes to an offsettable memory reference. Useful when accessing the high 8 bytes of SSE values. For a memref in (%rax), it generates	`%H0`	`8(%rax)`	`8[rax]`
`k`	Print the SImode name of the register.	`%k0`	`%eax`	`eax`
`l`	Print the label name with no punctuation.	`%l3`	`.L3`	`.L3`
`p`	Print raw symbol name (without syntax-specific prefixes).	`%p2`	`42`	`42`

`P`	If used for a function, print the PLT suffix and generate PIC code. For example, emit `foo@PLT` instead of 'foo' for the function foo(). If used for a constant, drop all syntax-specific prefixes and issue the bare constant. See `p` above.			
`q`	Print the DImode name of the register.	`%q0`	`%rax`	`rax`
`w`	Print the HImode name of the register.	`%w0`	`%ax`	`ax`
`z`	Print the opcode suffix for the size of the current integer operand (one of `b`/`w`/`l`/`q`).	`%z0`	`l`	

`V` is a special modifier which prints the name of the full integer register without `%`.

6.11.2.11 x86 Floating-Point `asm` Operands

On x86 targets, there are several rules on the usage of stack-like registers in the operands of an `asm`. These rules apply only to the operands that are stack-like registers:

1. Given a set of input registers that die in an `asm`, it is necessary to know which are implicitly popped by the `asm`, and which must be explicitly popped by GCC.

   An input register that is implicitly popped by the `asm` must be explicitly clobbered, unless it is constrained to match an output operand.

2. For any input register that is implicitly popped by an `asm`, it is necessary to know how to adjust the stack to compensate for the pop. If any non-popped input is closer to the top of the reg-stack than the implicitly popped register, it would not be possible to know what the stack looked like—it's not clear how the rest of the stack "slides up".

   All implicitly popped input registers must be closer to the top of the reg-stack than any input that is not implicitly popped.

   It is possible that if an input dies in an `asm`, the compiler might use the input register for an output reload. Consider this example:

   ```
   asm ("foo" : "=t" (a) : "f" (b));
   ```

   This code says that input `b` is not popped by the `asm`, and that the `asm` pushes a result onto the reg-stack, i.e., the stack is one deeper after the `asm` than it was before. But, it is possible that reload may think that it can use the same register for both the input and the output.

   To prevent this from happening, if any input operand uses the '`f`' constraint, all output register constraints must use the '`&`' early-clobber modifier.

   The example above is correctly written as:

   ```
   asm ("foo" : "=&t" (a) : "f" (b));
   ```

3. Some operands need to be in particular places on the stack. All output operands fall in this category—GCC has no other way to know which registers the outputs appear in unless you indicate this in the constraints.

   Output operands must specifically indicate which register an output appears in after an `asm`. '`=f`' is not allowed: the operand constraints must select a class with a single register.

4. Output operands may not be "inserted" between existing stack registers. Since no 387 opcode uses a read/write operand, all output operands are dead before the `asm`, and are pushed by the `asm`. It makes no sense to push anywhere but the top of the reg-stack.

Output operands must start at the top of the reg-stack: output operands may not "skip" a register.

5. Some `asm` statements may need extra stack space for internal calculations. This can be guaranteed by clobbering stack registers unrelated to the inputs and outputs.

This `asm` takes one input, which is internally popped, and produces two outputs.

```
asm ("fsincos" : "=t" (cos), "=u" (sin) : "0" (inp));
```

This `asm` takes two inputs, which are popped by the `fyl2xp1` opcode, and replaces them with one output. The `st(1)` clobber is necessary for the compiler to know that `fyl2xp1` pops both inputs.

```
asm ("fyl2xp1" : "=t" (result) : "0" (x), "u" (y) : "st(1)");
```

6.11.2.12 MSP430 Operand Modifiers

The list below describes the supported modifiers and their effects for MSP430.

Modifier	Description
`A`	Select low 16-bits of the constant/register/memory operand.
`B`	Select high 16-bits of the constant/register/memory operand.
`C`	Select bits 32-47 of the constant/register/memory operand.
`D`	Select bits 48-63 of the constant/register/memory operand.
`H`	Equivalent to `B` (for backwards compatibility).
`I`	Print the inverse (logical `NOT`) of the constant value.
`J`	Print an integer without a `#` prefix.
`L`	Equivalent to `A` (for backwards compatibility).
`O`	Offset of the current frame from the top of the stack.
`Q`	Use the `A` instruction postfix.
`R`	Inverse of condition code, for unsigned comparisons.
`W`	Subtract 16 from the constant value.
`X`	Use the `X` instruction postfix.
`Y`	Subtract 4 from the constant value.
`Z`	Subtract 1 from the constant value.
`b`	Append `.B`, `.W` or `.A` to the instruction, depending on the mode.
`d`	Offset 1 byte of a memory reference or constant value.
`e`	Offset 3 bytes of a memory reference or constant value.
`f`	Offset 5 bytes of a memory reference or constant value.
`g`	Offset 7 bytes of a memory reference or constant value.
`p`	Print the value of 2, raised to the power of the given constant. Used to select the specified bit position.
`r`	Inverse of condition code, for signed comparisons.
`x`	Equivalent to `X`, but only for pointers.

6.11.2.13 LoongArch Operand Modifiers

The list below describes the supported modifiers and their effects for LoongArch.

Modifier	Description
`d`	Same as `c`.
`i`	Print the character "`i`" if the operand is not a register.
`m`	Same as `c`, but the printed value is `operand - 1`.

`u` Print a LASX register.
`w` Print a LSX register.
`X` Print a constant integer operand in hexadecimal.
`z` Print the operand in its unmodified form, followed by a comma.

References to input and output operands in the assembler template of extended asm statements can use modifiers to affect the way the operands are formatted in the code output to the assembler. For example, the following code uses the 'w' modifier for LoongArch:

```
test-asm.c:

#include <lsxintrin.h>

__m128i foo (void)
{
__m128i  a,b,c;
__asm__ ("vadd.d %w0,%w1,%w2\n\t"
   :"=f" (c)
   :"f" (a),"f" (b));

return c;
}
```

The compile command for the test case is as follows:

```
gcc test-asm.c -mlsx -S -o test-asm.s
```

The assembly statement produces the following assembly code:

```
vadd.d $vr0,$vr0,$vr1
```

This is a 128-bit vector addition instruction, `c` (referred to in the template string as %0) is the output, and `a` (%1) and `b` (%2) are the inputs. `__m128i` is a vector data type defined in the file `lsxintrin.h` (See Section 7.13.13 [LoongArch SX Vector Intrinsics], page 894). The symbol '=f' represents a constraint using a floating-point register as an output type, and the 'f' in the input operand represents a constraint using a floating-point register operand, which can refer to the definition of a constraint (See Section 6.11.3 [Constraints], page 776) in gcc.

6.11.2.14 RISC-V Operand Modifiers

The list below describes the supported modifiers and their effects for RISC-V.

Modifier	Description
`z`	Print "`zero`" instead of 0 if the operand is an immediate with a value of zero.
`i`	Print the character "`i`" if the operand is an immediate.
`N`	Print the register encoding as integer (0 - 31).
`H`	Print the name of the next register for integer.

6.11.2.15 SH Operand Modifiers

The list below describes the supported modifiers and their effects for the SH family of processors.

Modifier	Description
`.`	Print ".s" if the instruction needs a delay slot.
`,`	Print "LOCAL_LABEL_PREFIX".
`@`	Print "trap", "rte" or "rts" depending on the interrupt pragma used.
`#`	Print "nop" if there is nothing to put in the delay slot.
`'`	Print likelihood suffix ("/u" for unlikely).
`>`	Print branch target if "-fverbose-asm".
`O`	Require a constant operand and print the constant expression with no punctuation.
`R`	Print the "LSW" of a dp value - changes if in little endian.
`S`	Print the "MSW" of a dp value - changes if in little endian.
`T`	Print the next word of a dp value - same as "R" in big endian mode.
`M`	Print ".b ", ".w", ".l", ".s", ".d", suffix if operand is a MEM.
`N`	Print "r63" if the operand is "const_int 0".
`d`	Print a "V2SF" as "dN" instead of "fpN".
`m`	Print the pair "base,offset" or "base,index" for LD and ST.
`U`	Like "%m" for "LD" and "ST", "HI" and "LO".
`V`	Print the position of a single bit set.
`W`	Print the position of a single bit cleared.
`t`	Print a memory address which is a register.
`u`	Print the lowest 16 bits of "CONST_INT", as an unsigned value.
`o`	Print an operator.

6.11.3 Constraints for `asm` Operands

Here are specific details on what constraint letters you can use with `asm` operands. Constraints can say whether an operand may be in a register, and which kinds of register; whether the operand can be a memory reference, and which kinds of address; whether the operand may be an immediate constant, and which possible values it may have. Constraints can also require two operands to match. Side-effects aren't allowed in operands of inline `asm`, unless '<' or '>' constraints are used, because there is no guarantee that the side effects will happen exactly once in an instruction that can update the addressing register.

6.11.3.1 Simple Constraints

The simplest kind of constraint is a string full of letters, each of which describes one kind of operand that is permitted. Here are the letters that are allowed:

whitespace

Whitespace characters are ignored and can be inserted at any position except the first. This enables each alternative for different operands to be visually aligned in the machine description even if they have different number of constraints and modifiers.

'm' A memory operand is allowed, with any kind of address that the machine supports in general. Note that the letter used for the general memory constraint can be re-defined by a back end using the `TARGET_MEM_CONSTRAINT` macro.

'o' A memory operand is allowed, but only if the address is *offsettable*. This means that adding a small integer (actually, the width in bytes of the operand, as determined by its machine mode) may be added to the address and the result is also a valid memory address.

For example, an address which is constant is offsettable; so is an address that is the sum of a register and a constant (as long as a slightly larger constant is also within the range of address-offsets supported by the machine); but an autoincrement or autodecrement address is not offsettable. More complicated indirect/indexed addresses may or may not be offsettable depending on the other addressing modes that the machine supports.

Note that in an output operand which can be matched by another operand, the constraint letter '`o`' is valid only when accompanied by both '`<`' (if the target machine has predecrement addressing) and '`>`' (if the target machine has preincrement addressing).

'`V`' A memory operand that is not offsettable. In other words, anything that would fit the '`m`' constraint but not the '`o`' constraint.

'`<`' A memory operand with autodecrement addressing (either predecrement or postdecrement) is allowed. In inline `asm` this constraint is only allowed if the operand is used exactly once in an instruction that can handle the side effects. Not using an operand with '`<`' in constraint string in the inline `asm` pattern at all or using it in multiple instructions isn't valid, because the side effects wouldn't be performed or would be performed more than once. Furthermore, on some targets the operand with '`<`' in constraint string must be accompanied by special instruction suffixes like `%U0` instruction suffix on PowerPC or `%P0` on IA-64.

'`>`' A memory operand with autoincrement addressing (either preincrement or postincrement) is allowed. In inline `asm` the same restrictions as for '`<`' apply.

'`r`' A register operand is allowed provided that it is in a general register.

'`{r}`' An operand is bound to hard register '`r`' which may be any general, floating-point, or vector register except a fixed register like a stack pointer register. The set of fixed registers is target dependent.

'`i`' An immediate integer operand (one with constant value) is allowed. This includes symbolic constants whose values will be known only at assembly time or later.

'`n`' An immediate integer operand with a known numeric value is allowed. Many systems cannot support assembly-time constants for operands less than a word wide. Constraints for these operands should use '`n`' rather than '`i`'.

'`I`', '`J`', '`K`', . . . '`P`'
Other letters in the range '`I`' through '`P`' may be defined in a machine-dependent fashion to permit immediate integer operands with explicit integer values in specified ranges. For example, on the 68000, '`I`' is defined to stand for the range of values 1 to 8. This is the range permitted as a shift count in the shift instructions.

'E' An immediate floating operand (expression code `const_double`) is allowed, but only if the target floating point format is the same as that of the host machine (on which the compiler is running).

'F' An immediate floating operand (expression code `const_double` or `const_vector`) is allowed.

'G', 'H' 'G' and 'H' may be defined in a machine-dependent fashion to permit immediate floating operands in particular ranges of values.

's' An immediate integer operand whose value is not an explicit integer is allowed.

This might appear strange; if an insn allows a constant operand with a value not known at compile time, it certainly must allow any known value. So why use 's' instead of 'i'? Sometimes it allows better code to be generated.

For example, on the 68000 in a fullword instruction it is possible to use an immediate operand; but if the immediate value is between −128 and 127, better code results from loading the value into a register and using the register. This is because the load into the register can be done with a 'moveq' instruction. We arrange for this to happen by defining the letter 'K' to mean "any integer outside the range −128 to 127", and then specifying 'Ks' in the operand constraints.

'g' Any register, memory or immediate integer operand is allowed, except for registers that are not general registers.

'X' Any operand whatsoever is allowed.

'0', '1', '2', ... '9'

An operand that matches the specified operand number is allowed. If a digit is used together with letters within the same alternative, the digit should come last.

This number is allowed to be more than a single digit. If multiple digits are encountered consecutively, they are interpreted as a single decimal integer. There is scant chance for ambiguity, since to-date it has never been desirable that '10' be interpreted as matching either operand 1 *or* operand 0. Should this be desired, one can use multiple alternatives instead.

This is called a *matching constraint* and what it really means is that the assembler has only a single operand that fills two roles which `asm` distinguishes. For example, an add instruction uses two input operands and an output operand, but on most CISC machines an add instruction really has only two operands, one of them an input-output operand:

```
addl #35,r12
```

Matching constraints are used in these circumstances. More precisely, the two operands that match must include one input-only operand and one output-only operand. Moreover, the digit must be a smaller number than the number of the operand that uses it in the constraint.

'p' An operand that is a valid memory address is allowed. This is for "load address" and "push address" instructions.

'p' in the constraint must be accompanied by `address_operand` as the predicate in the `match_operand`. This predicate interprets the mode specified in the match_operand as the mode of the memory reference for which the address would be valid.

':' This constraint, allowed only in input operands, says the inline asm pattern defines specific function or variable symbol. The constraint shouldn't be mixed with other constraints on the same operand and the operand should be address of a function or non-automatic variable. Best used with the 'cc' modifier when printing the operand, so that even in position independent code it prints as a label.

```
void foo (void);
asm (".globl %cc0; %cc0: ret" : : ":" (foo));
```

other-letters

Other letters can be defined in machine-dependent fashion to stand for particular classes of registers or other arbitrary operand types. 'd', 'a' and 'f' are defined on the 68000/68020 to stand for data, address and floating point registers.

6.11.3.2 Multiple Alternative Constraints

Sometimes a single instruction has multiple alternative sets of possible operands. For example, on the 68000, a logical-or instruction can combine register or an immediate value into memory, or it can combine any kind of operand into a register; but it cannot combine one memory location into another.

These constraints are represented as multiple alternatives. An alternative can be described by a series of letters for each operand. The overall constraint for an operand is made from the letters for this operand from the first alternative, a comma, the letters for this operand from the second alternative, a comma, and so on until the last alternative. All operands for a single instruction must have the same number of alternatives.

So the first alternative for the 68000's logical-or could be written as `"+m" (output) : "ir" (input)`. The second could be `"+r" (output): "irm" (input)`. However, the fact that two memory locations cannot be used in a single instruction prevents simply using `"+rm" (output) : "irm" (input)`. Using multi-alternatives, this might be written as `"+m,r" (output) : "ir,irm" (input)`. This describes all the available alternatives to the compiler, allowing it to choose the most efficient one for the current conditions.

There is no way within the template to determine which alternative was chosen. However you may be able to wrap your asm statements with builtins such as __builtin_constant_p to achieve the desired results.

6.11.3.3 Constraint Modifier Characters

Here are constraint modifier characters.

'=' Means that this operand is written to by this instruction: the previous value is discarded and replaced by new data.

'+' Means that this operand is both read and written by the instruction.

When the compiler fixes up the operands to satisfy the constraints, it needs to know which operands are read by the instruction and which are written by it. '=' identifies an operand which is only written; '+' identifies an operand that is both read and written; all other operands are assumed to only be read.

If you specify '=' or '+' in a constraint, you put it in the first character of the constraint string.

'&' Means (in a particular alternative) that this operand is an *earlyclobber* operand, which is written before the instruction is finished using the input operands. Therefore, this operand may not lie in a register that is read by the instruction or as part of any memory address.

'&' applies only to the alternative in which it is written. In constraints with multiple alternatives, sometimes one alternative requires '&' while others do not. See, for example, the 'movdf' insn of the 68000.

An operand which is read by the instruction can be tied to an earlyclobber operand if its only use as an input occurs before the early result is written. Adding alternatives of this form often allows GCC to produce better code when only some of the read operands can be affected by the earlyclobber. See, for example, the 'mulsi3' insn of the ARM.

Furthermore, if the *earlyclobber* operand is also a read/write operand, then that operand is written only after it's used.

'&' does not obviate the need to write '=' or '+'. As *earlyclobber* operands are always written, a read-only *earlyclobber* operand is ill-formed and will be rejected by the compiler.

'%' Declares the instruction to be commutative for this operand and the following operand. This means that the compiler may interchange the two operands if that is the cheapest way to make all operands fit the constraints. '%' applies to all alternatives and must appear as the first character in the constraint. Only read-only operands can use '%'.

GCC can only handle one commutative pair in an asm; if you use more, the compiler may fail. Note that you need not use the modifier if the two alternatives are strictly identical; this would only waste time in the reload pass.

'-' Says that the selected following constraints within the same alternative should be matched differently. Normally in PIC code symbolic operands in constraints like 'i', 's' or 'n' are not allowed at all or severely restricted. The '-' modifier, which is only allowed outside of functions, allows symbolic operands even in PIC code. This modifier is usually used together with the `cc` operand modifier.

```
extern void foo (void), bar (void);
int v;
extern int w;
asm (".globl %cc0, %cc2; .text; %cc0: call %cc1; ret; .data; %cc2: .word %cc3"
     :: ":" (foo), "-s" (&bar), ":" (&w), "-i" (&v));
```

This asm declaration tells the compiler it defines function `foo` and variable `w` and uses function `bar` and variable `v`. This will compile even with PIC, but it is up to the user to ensure it will assemble correctly and have the expected behavior.

6.11.3.4 Constraints for Particular Machines

Whenever possible, you should use the general-purpose constraint letters in `asm` arguments, since they will convey meaning more readily to people reading your code. Failing that, use the constraint letters that usually have very similar meanings across architectures. The most commonly used constraints are '`m`' and '`r`' (for memory and general-purpose registers respectively; see Section 6.11.3.1 [Simple Constraints], page 776), and '`I`', usually the letter indicating the most common immediate-constant format.

Each architecture defines additional constraints. These constraints are used by the compiler itself for instruction generation, as well as for `asm` statements; therefore, some of the constraints are not particularly useful for `asm`. Here is a summary of some of the machine-dependent constraints available on some particular machines; it includes both constraints that are useful for `asm` and constraints that aren't. The compiler source file mentioned in the table heading for each architecture is the definitive reference for the meanings of that architecture's constraints.

AArch64 family—`config/aarch64/constraints.md`

`k` The stack pointer register (`SP`)

`w` Floating point register, Advanced SIMD vector register or SVE vector register

`x` Like `w`, but restricted to registers 0 to 15 inclusive.

`y` Like `w`, but restricted to registers 0 to 7 inclusive.

`Upl` One of the low eight SVE predicate registers (`P0` to `P7`)

`Upa` Any of the SVE predicate registers (`P0` to `P15`)

`I` Integer constant that is valid as an immediate operand in an `ADD` instruction

`J` Integer constant that is valid as an immediate operand in a `SUB` instruction (once negated)

`K` Integer constant that can be used with a 32-bit logical instruction

`L` Integer constant that can be used with a 64-bit logical instruction

`M` Integer constant that is valid as an immediate operand in a 32-bit `MOV` pseudo instruction. The `MOV` may be assembled to one of several different machine instructions depending on the value

`N` Integer constant that is valid as an immediate operand in a 64-bit `MOV` pseudo instruction

`S` An absolute symbolic address or a label reference

`Y` Floating point constant zero

`Z` Integer constant zero

`Ush` The high part (bits 12 and upwards) of the pc-relative address of a symbol within 4GB of the instruction

`Q` A memory address which uses a single base register with no offset

`Ump` A memory address suitable for a load/store pair instruction in SI, DI, SF and DF modes

AMD GCN —`config/gcn/constraints.md`

`I` Immediate integer in the range −16 to 64

`J` Immediate 16-bit signed integer

`Kf` Immediate constant −1

`L` Immediate 15-bit unsigned integer

`A` Immediate constant that can be inlined in an instruction encoding: integer −16..64, or float 0.0, +/−0.5, +/−1.0, +/−2.0, +/−4.0, 1.0/(2.0*PI)

`B` Immediate 32-bit signed integer that can be attached to an instruction encoding

`C` Immediate 32-bit integer in range −16..4294967295 (i.e. 32-bit unsigned integer or '`A`' constraint)

`DA` Immediate 64-bit constant that can be split into two '`A`' constants

`DB` Immediate 64-bit constant that can be split into two '`B`' constants

`U` Any `unspec`

`Y` Any `symbol_ref` or `label_ref`

`v` VGPR register

`a` Accelerator VGPR register (CDNA1 onwards)

`Sg` SGPR register

`SD` SGPR registers valid for instruction destinations, including VCC, M0 and EXEC

`SS` SGPR registers valid for instruction sources, including VCC, M0, EXEC and SCC

`Sm` SGPR registers valid as a source for scalar memory instructions (excludes M0 and EXEC)

`Sv` SGPR registers valid as a source or destination for vector instructions (excludes EXEC)

`ca` All condition registers: SCC, VCCZ, EXECZ

`cs` Scalar condition register: SCC

`cV` Vector condition register: VCC, VCC_LO, VCC_HI

`e` EXEC register (EXEC_LO and EXEC_HI)

`RB` Memory operand with address space suitable for `buffer_*` instructions

`RF` Memory operand with address space suitable for `flat_*` instructions

`RS` Memory operand with address space suitable for `s_*` instructions

`RL` Memory operand with address space suitable for `ds_*` LDS instructions

`RG` Memory operand with address space suitable for `ds_*` GDS instructions

`RD` Memory operand with address space suitable for any `ds_*` instructions

`RM` Memory operand with address space suitable for `global_*` instructions

ARC —`config/arc/constraints.md`

`q` Registers usable in ARCompact 16-bit instructions: `r0`-`r3`, `r12`-`r15`. This constraint can only match when the `-mq` option is in effect.

`e` Registers usable as base-regs of memory addresses in ARCompact 16-bit memory instructions: `r0`-`r3`, `r12`-`r15`, `sp`. This constraint can only match when the `-mq` option is in effect.

`D` ARC FPX (dpfp) 64-bit registers. `D0`, `D1`.

`I` A signed 12-bit integer constant.

`Cal` constant for arithmetic/logical operations. This might be any constant that can be put into a long immediate by the assmbler or linker without involving a PIC relocation.

`K` A 3-bit unsigned integer constant.

`L` A 6-bit unsigned integer constant.

`CnL` One's complement of a 6-bit unsigned integer constant.

`CmL` Two's complement of a 6-bit unsigned integer constant.

`M` A 5-bit unsigned integer constant.

`O` A 7-bit unsigned integer constant.

`P` A 8-bit unsigned integer constant.

`H` Any const_double value.

ARM family—`config/arm/constraints.md`

`h` In Thumb state, the core registers `r8`-`r15`.

`k` The stack pointer register.

`l` In Thumb State the core registers `r0`-`r7`. In ARM state this is an alias for the `r` constraint.

`t` VFP floating-point registers `s0`-`s31`. Used for 32 bit values.

`w` VFP floating-point registers `d0`-`d31` and the appropriate subset `d0`-`d15` based on command line options. Used for 64 bit values only. Not valid for Thumb1.

`G` The floating-point constant 0.0

`I` Integer that is valid as an immediate operand in a data processing instruction. That is, an integer in the range 0 to 255 rotated by a multiple of 2

`J` Integer in the range −4095 to 4095

`K` Integer that satisfies constraint '`I`' when inverted (ones complement)

`L` Integer that satisfies constraint '`I`' when negated (twos complement)

`M` Integer in the range 0 to 32

`Q` A memory reference where the exact address is in a single register (''`m`'' is preferable for `asm` statements)

`R` An item in the constant pool

`S` A symbol in the text segment of the current file

`Uv` A memory reference suitable for VFP load/store insns (reg+constant offset)

`Uq` A memory reference suitable for the ARMv4 ldrsb instruction.

AVR family—`config/avr/constraints.md`

`l` Registers from r0 to r15

`a` Registers from r16 to r23

`d` Registers from r16 to r31

`w` Registers from r24 to r31. These registers can be used in '`adiw`' command

`e` Pointer register (r26–r31)

`b` Base pointer register (r28–r31)

`q` Stack pointer register (SPH:SPL)

`t` Temporary register r0

`x` Register pair X (r27:r26)

`y` Register pair Y (r29:r28)

`z` Register pair Z (r31:r30)

`I` Constant greater than −1, less than 64

`J` Constant greater than −64, less than 1

`K` Constant integer 2

`L` Constant integer 0

`M` Constant that fits in 8 bits

`N` Constant integer -1

`O` Constant integer 8, 16, or 24

`P` Constant integer 1

`G` A floating point constant 0.0

`Q` A memory address based on Y or Z pointer with displacement.

Blackfin family—`config/bfin/constraints.md`

`a` P register

`d` D register

`z` A call clobbered P register.

`q`*n* A single register. If *n* is in the range 0 to 7, the corresponding D register. If it is `A`, then the register P0.

`D` Even-numbered D register

`W` Odd-numbered D register

`e` Accumulator register.

`A` Even-numbered accumulator register.

`B` Odd-numbered accumulator register.

`b` I register

`v` B register

`f` M register

`c` Registers used for circular buffering, i.e. I, B, or L registers.

`C` The CC register.

`t` LT0 or LT1.

`k` LC0 or LC1.

`u` LB0 or LB1.

`x` Any D, P, B, M, I or L register.

`y` Additional registers typically used only in prologues and epilogues: RETS, RETN, RETI, RETX, RETE, ASTAT, SEQSTAT and USP.

`w` Any register except accumulators or CC.

`Ksh` Signed 16 bit integer (in the range -32768 to 32767)

`Kuh` Unsigned 16 bit integer (in the range 0 to 65535)

`Ks7` Signed 7 bit integer (in the range -64 to 63)

`Ku7` Unsigned 7 bit integer (in the range 0 to 127)

`Ku5` Unsigned 5 bit integer (in the range 0 to 31)

`Ks4` Signed 4 bit integer (in the range −8 to 7)

`Ks3` Signed 3 bit integer (in the range −3 to 4)

`Ku3` Unsigned 3 bit integer (in the range 0 to 7)

`P`*n* Constant *n*, where *n* is a single-digit constant in the range 0 to 4.

`PA` An integer equal to one of the MACFLAG_XXX constants that is suitable for use with either accumulator.

`PB` An integer equal to one of the MACFLAG_XXX constants that is suitable for use only with accumulator A1.

`M1` Constant 255.

`M2` Constant 65535.

`J` An integer constant with exactly a single bit set.

`L` An integer constant with all bits set except exactly one.

`H`
`Q` Any SYMBOL_REF.

C-SKY—`config/csky/constraints.md`

`a` The mini registers r0 - r7.

`b` The low registers r0 - r15.

`c` C register.

`y` HI and LO registers.

`l` LO register.

`h` HI register.

`v` Vector registers.

`z` Stack pointer register (SP).

`Q` A memory address which uses a base register with a short offset or with a index register with its scale.

`W` A memory address which uses a base register with a index register with its scale.

Epiphany—`config/epiphany/constraints.md`

`U16` An unsigned 16-bit constant.

`K` An unsigned 5-bit constant.

`L` A signed 11-bit constant.

`Cm1` A signed 11-bit constant added to −1. Can only match when the `-m1reg-`*`reg`* option is active.

`Cl1` Left-shift of −1, i.e., a bit mask with a block of leading ones, the rest being a block of trailing zeroes. Can only match when the `-m1reg-`*`reg`* option is active.

`Cr1` Right-shift of −1, i.e., a bit mask with a trailing block of ones, the rest being zeroes. Or to put it another way, one less than a power of two. Can only match when the `-m1reg-reg` option is active.

`Cal` Constant for arithmetic/logical operations. This is like `i`, except that for position independent code, no symbols / expressions needing relocations are allowed.

`Csy` Symbolic constant for call/jump instruction.

`Rcs` The register class usable in short insns. This is a register class constraint, and can thus drive register allocation. This constraint won't match unless `-mprefer-short-insn-regs` is in effect.

`Rsc` The register class of registers that can be used to hold a sibcall call address. I.e., a caller-saved register.

`Rct` Core control register class.

`Rgs` The register group usable in short insns. This constraint does not use a register class, so that it only passively matches suitable registers, and doesn't drive register allocation.

`Rra` Matches the return address if it can be replaced with the link register.

`Rcc` Matches the integer condition code register.

`Sra` Matches the return address if it is in a stack slot.

`Cfm` Matches control register values to switch fp mode, which are encapsulated in `UNSPEC_FP_MODE`.

FRV—`config/frv/frv.h`

`a` Register in the class `ACC_REGS` (`acc0` to `acc7`).

`b` Register in the class `EVEN_ACC_REGS` (`acc0` to `acc7`).

`c` Register in the class `CC_REGS` (`fcc0` to `fcc3` and `icc0` to `icc3`).

`d` Register in the class `GPR_REGS` (`gr0` to `gr63`).

`e` Register in the class `EVEN_REGS` (`gr0` to `gr63`). Odd registers are excluded not in the class but through the use of a machine mode larger than 4 bytes.

`f` Register in the class `FPR_REGS` (`fr0` to `fr63`).

`h` Register in the class `FEVEN_REGS` (`fr0` to `fr63`). Odd registers are excluded not in the class but through the use of a machine mode larger than 4 bytes.

`l` Register in the class `LR_REG` (the `lr` register).

`q` Register in the class `QUAD_REGS` (`gr2` to `gr63`). Register numbers not divisible by 4 are excluded not in the class but through the use of a machine mode larger than 8 bytes.

`t` Register in the class `ICC_REGS` (`icc0` to `icc3`).

`u` Register in the class `FCC_REGS` (`fcc0` to `fcc3`).

`v` Register in the class `ICR_REGS` (`cc4` to `cc7`).

`w` Register in the class `FCR_REGS` (`cc0` to `cc3`).

`x` Register in the class `QUAD_FPR_REGS` (`fr0` to `fr63`). Register numbers not divisible by 4 are excluded not in the class but through the use of a machine mode larger than 8 bytes.

`z` Register in the class `SPR_REGS` (`lcr` and `lr`).

`A` Register in the class `QUAD_ACC_REGS` (`acc0` to `acc7`).

`B` Register in the class `ACCG_REGS` (`accg0` to `accg7`).

`C` Register in the class `CR_REGS` (`cc0` to `cc7`).

`G` Floating point constant zero

`I` 6-bit signed integer constant

`J` 10-bit signed integer constant

`L` 16-bit signed integer constant

`M` 16-bit unsigned integer constant

`N` 12-bit signed integer constant that is negative—i.e. in the range of -2048 to -1

`O` Constant zero

`P` 12-bit signed integer constant that is greater than zero—i.e. in the range of 1 to 2047.

FT32—`config/ft32/constraints.md`

`A` An absolute address

`B` An offset address

`W` A register indirect memory operand

`e` An offset address.

`f` An offset address.

`O` The constant zero or one

`I` A 16-bit signed constant (-32768 . . . 32767)

`w` A bitfield mask suitable for bext or bins

`x` An inverted bitfield mask suitable for bext or bins

`L` A 16-bit unsigned constant, multiple of 4 (0 . . . 65532)

`S` A 20-bit signed constant (-524288 . . . 524287)

`b` A constant for a bitfield width (1 . . . 16)

`KA` A 10-bit signed constant (−512 . . . 511)

Hewlett-Packard PA-RISC—`config/pa/pa.h`

`a` General register 1

`f` Floating point register

`q` Shift amount register

`x` Floating point register (deprecated)

`y` Upper floating point register (32-bit), floating point register (64-bit)

`Z` Any register

`I` Signed 11-bit integer constant

`J` Signed 14-bit integer constant

`K` Integer constant that can be deposited with a `zdepi` instruction

`L` Signed 5-bit integer constant

`M` Integer constant 0

`N` Integer constant that can be loaded with a `ldil` instruction

`O` Integer constant whose value plus one is a power of 2

`P` Integer constant that can be used for `and` operations in `depi` and `extru` instructions

`S` Integer constant 31

`U` Integer constant 63

`G` Floating-point constant 0.0

`A` A `lo_sum` data-linkage-table memory operand

`Q` A memory operand that can be used as the destination operand of an integer store instruction

`R` A scaled or unscaled indexed memory operand

`T` A memory operand for floating-point loads and stores

`W` A register indirect memory operand

Intel IA-64—`config/ia64/ia64.h`

`a` General register `r0` to `r3` for `addl` instruction

`b` Branch register

`c` Predicate register (‘`c`’ as in “conditional”)

`d` Application register residing in M-unit

`e` Application register residing in I-unit

`f` Floating-point register

`m` Memory operand. If used together with '`<`' or '`>`', the operand can have postincrement and postdecrement which require printing with '`%Pn`' on IA-64.

`G` Floating-point constant 0.0 or 1.0

`I` 14-bit signed integer constant

`J` 22-bit signed integer constant

`K` 8-bit signed integer constant for logical instructions

`L` 8-bit adjusted signed integer constant for compare pseudo-ops

`M` 6-bit unsigned integer constant for shift counts

`N` 9-bit signed integer constant for load and store postincrements

`O` The constant zero

`P` 0 or −1 for `dep` instruction

`Q` Non-volatile memory for floating-point loads and stores

`R` Integer constant in the range 1 to 4 for `shladd` instruction

`S` Memory operand except postincrement and postdecrement. This is now roughly the same as '`m`' when not used together with '`<`' or '`>`'.

M32C—`config/m32c/m32c.cc`

`Rsp`
`Rfb`
`Rsb` '`$sp`', '`$fb`', '`$sb`'.

`Rcr` Any control register, when they're 16 bits wide (nothing if control registers are 24 bits wide)

`Rcl` Any control register, when they're 24 bits wide.

`R0w`
`R1w`
`R2w`
`R3w` $r0, $r1, $r2, $r3.

`R02` $r0 or $r2, or $r2r0 for 32 bit values.

`R13` $r1 or $r3, or $r3r1 for 32 bit values.

`Rdi` A register that can hold a 64 bit value.

`Rhl` $r0 or $r1 (registers with addressable high/low bytes)

`R23` $r2 or $r3

`Raa` Address registers

`Raw` Address registers when they're 16 bits wide.

`Ral` Address registers when they're 24 bits wide.

`Rqi` Registers that can hold QI values.

`Rad` Registers that can be used with displacements ($a0, $a1, $sb).

`Rsi` Registers that can hold 32 bit values.

`Rhi` Registers that can hold 16 bit values.

`Rhc` Registers chat can hold 16 bit values, including all control registers.

`Rra` $r0 through R1, plus $a0 and $a1.

`Rfl` The flags register.

`Rmm` The memory-based pseudo-registers $mem0 through $mem15.

`Rpi` Registers that can hold pointers (16 bit registers for r8c, m16c; 24 bit registers for m32cm, m32c).

`Rpa` Matches multiple registers in a PARALLEL to form a larger register. Used to match function return values.

`Is3` −8 . . . 7

`IS1` −128 . . . 127

`IS2` −32768 . . . 32767

`IU2` 0 . . . 65535

`In4` −8 . . . −1 or 1 . . . 8

`In5` −16 . . . −1 or 1 . . . 16

`In6` −32 . . . −1 or 1 . . . 32

`IM2` −65536 . . . −1

`Ilb` An 8 bit value with exactly one bit set.

`Ilw` A 16 bit value with exactly one bit set.

`Sd` The common src/dest memory addressing modes.

`Sa` Memory addressed using $a0 or $a1.

`Si` Memory addressed with immediate addresses.

`Ss` Memory addressed using the stack pointer ($sp).

`Sf` Memory addressed using the frame base register ($fb).

`Ss` Memory addressed using the small base register ($sb).

`S1` $r1h

LoongArch—`config/loongarch/constraints.md`

`f` A floating-point or vector register (if available).

`k` A memory operand whose address is formed by a base register and (optionally scaled) index register.

`l` A signed 16-bit constant.

`m` A memory operand whose address is formed by a base register and offset that is suitable for use in instructions with the same addressing mode as `st.w` and `ld.w`.

`q` A general-purpose register except for $r0 and $r1 (for the csrxchg instruction)

`I` A signed 12-bit constant (for arithmetic instructions).

`K` An unsigned 12-bit constant (for logic instructions).

`M` A constant that cannot be loaded using `lui`, `addiu` or `ori`.

`N` A constant in the range -65535 to -1 (inclusive).

`O` A signed 15-bit constant.

`P` A constant in the range 1 to 65535 (inclusive).

`R` An address that can be used in a non-macro load or store.

`ZB` An address that is held in a general-purpose register. The offset is zero.

`ZC` A memory operand whose address is formed by a base register and offset that is suitable for use in instructions with the same addressing mode as `ll.w` and `sc.w`.

MicroBlaze—`config/microblaze/constraints.md`

`d` A general register (`r0` to `r31`).

`z` A status register (`rmsr`, `$fcc1` to `$fcc7`).

MIPS—`config/mips/constraints.md`

`d` A general-purpose register. This is equivalent to `r` unless generating MIPS16 code, in which case the MIPS16 register set is used.

`f` A floating-point register (if available).

`h` Formerly the `hi` register. This constraint is no longer supported.

`l` The `lo` register. Use this register to store values that are no bigger than a word.

`x` The concatenated `hi` and `lo` registers. Use this register to store doubleword values.

`c` A register suitable for use in an indirect jump. This will always be `$25` for `-mabicalls`.

`v` Register `$3`. Do not use this constraint in new code; it is retained only for compatibility with glibc.

`y` Equivalent to `r`; retained for backwards compatibility.

`z` A floating-point condition code register.

`I` A signed 16-bit constant (for arithmetic instructions).

`J` Integer zero.

`K` An unsigned 16-bit constant (for logic instructions).

`L` A signed 32-bit constant in which the lower 16 bits are zero. Such constants can be loaded using `lui`.

`M` A constant that cannot be loaded using `lui`, `addiu` or `ori`.

`N` A constant in the range −65535 to −1 (inclusive).

`O` A signed 15-bit constant.

`P` A constant in the range 1 to 65535 (inclusive).

`G` Floating-point zero.

`R` An address that can be used in a non-macro load or store.

`ZC` A memory operand whose address is formed by a base register and offset that is suitable for use in instructions with the same addressing mode as `ll` and `sc`.

`ZD` An address suitable for a `prefetch` instruction, or for any other instruction with the same addressing mode as `prefetch`.

Motorola 680x0—`config/m68k/constraints.md`

`a` Address register

`d` Data register

`f` 68881 floating-point register, if available

`I` Integer in the range 1 to 8

`J` 16-bit signed number

`K` Signed number whose magnitude is greater than 0x80

`L` Integer in the range −8 to −1

`M` Signed number whose magnitude is greater than 0x100

`N` Range 24 to 31, rotatert:SI 8 to 1 expressed as rotate

`O` 16 (for rotate using swap)

`P` Range 8 to 15, rotatert:HI 8 to 1 expressed as rotate

`R` Numbers that mov3q can handle

`G` Floating point constant that is not a 68881 constant

`S` Operands that satisfy 'm' when -mpcrel is in effect

`T` Operands that satisfy 's' when -mpcrel is not in effect

`Q` Address register indirect addressing mode

`U` Register offset addressing

`W` const_call_operand

`Cs` symbol_ref or const

`Ci` const_int

`C0` const_int 0

`Cj` Range of signed numbers that don't fit in 16 bits

`Cmvq` Integers valid for mvq

`Capsw` Integers valid for a moveq followed by a swap

`Cmvz` Integers valid for mvz

`Cmvs` Integers valid for mvs

`Ap` push_operand

`Ac` Non-register operands allowed in clr

Moxie—`config/moxie/constraints.md`

`A` An absolute address

`B` An offset address

`W` A register indirect memory operand

`I` A constant in the range of 0 to 255.

`N` A constant in the range of 0 to −255.

MSP430–`config/msp430/constraints.md`

`R12` Register R12.

`R13` Register R13.

`K` Integer constant 1.

`L` Integer constant -1^20..1^19.

`M` Integer constant 1-4.

`Ya` Memory references which do not require an extended MOVX instruction.

`Yl` Memory reference, labels only.

`Ys` Memory reference, stack only.

NDS32—`config/nds32/constraints.md`

`w` LOW register class $r0 to $r7 constraint for V3/V3M ISA.

`l` LOW register class $r0 to $r7.

`d` MIDDLE register class $r0 to $r11, $r16 to $r19.

`h` HIGH register class $r12 to $r14, $r20 to $r31.

`t` Temporary assist register $ta (i.e. $r15).

`k` Stack register $sp.

`Iu03` Unsigned immediate 3-bit value.

`In03` Negative immediate 3-bit value in the range of −7–0.

`Iu04` Unsigned immediate 4-bit value.

`Is05` Signed immediate 5-bit value.

`Iu05` Unsigned immediate 5-bit value.

`In05` Negative immediate 5-bit value in the range of −31–0.

`Ip05` Unsigned immediate 5-bit value for movpi45 instruction with range 16–47.

`Iu06` Unsigned immediate 6-bit value constraint for addri36.sp instruction.

`Iu08` Unsigned immediate 8-bit value.

`Iu09` Unsigned immediate 9-bit value.

`Is10` Signed immediate 10-bit value.

`Is11` Signed immediate 11-bit value.

`Is15` Signed immediate 15-bit value.

`Iu15` Unsigned immediate 15-bit value.

`Ic15` A constant which is not in the range of imm15u but ok for bclr instruction.

`Ie15` A constant which is not in the range of imm15u but ok for bset instruction.

`It15` A constant which is not in the range of imm15u but ok for btgl instruction.

`Ii15` A constant whose compliment value is in the range of imm15u and ok for bitci instruction.

`Is16` Signed immediate 16-bit value.

`Is17` Signed immediate 17-bit value.

`Is19` Signed immediate 19-bit value.

`Is20` Signed immediate 20-bit value.

`Ihig` The immediate value that can be simply set high 20-bit.

`Izeb` The immediate value 0xff.

`Izeh` The immediate value 0xffff.

`Ixls` The immediate value 0x01.

`Ix11` The immediate value 0x7ff.

`Ibms` The immediate value with power of 2.

`Ifex` The immediate value with power of 2 minus 1.

`U33` Memory constraint for 333 format.

`U45` Memory constraint for 45 format.

`U37` Memory constraint for 37 format.

OpenRISC—`config/or1k/constraints.md`

`I` Integer that is valid as an immediate operand in an instruction taking a signed 16-bit number. Range −32768 to 32767.

`K` Integer that is valid as an immediate operand in an instruction taking an unsigned 16-bit number. Range 0 to 65535.

`M` Signed 16-bit constant shifted left 16 bits. (Used with `l.movhi`)

`O` Zero

PDP-11—`config/pdp11/constraints.md`

`a` Floating point registers AC0 through AC3. These can be loaded from/to memory with a single instruction.

`d` Odd numbered general registers (R1, R3, R5). These are used for 16-bit multiply operations.

`D` A memory reference that is encoded within the opcode, but not auto-increment or auto-decrement.

`f` Any of the floating point registers (AC0 through AC5).

`G` Floating point constant 0.

`h` Floating point registers AC4 and AC5. These cannot be loaded from/to memory with a single instruction.

`I` An integer constant that fits in 16 bits.

`J` An integer constant whose low order 16 bits are zero.

`K` An integer constant that does not meet the constraints for codes '`I`' or '`J`'.

`L` The integer constant 1.

`M` The integer constant −1.

`N` The integer constant 0.

`O` Integer constants 0 through 3; shifts by these amounts are handled as multiple single-bit shifts rather than a single variable-length shift.

`Q` A memory reference which requires an additional word (address or offset) after the opcode.

`R` A memory reference that is encoded within the opcode.

PowerPC and IBM RS6000—`config/rs6000/constraints.md`

`r` A general purpose register (GPR), `r0`. . . `r31`.

`b` A base register. Like `r`, but `r0` is not allowed, so `r1...r31`.

`f` A floating point register (FPR), `f0...f31`.

`d` A floating point register. This is the same as `f` nowadays; historically `f` was for single-precision and `d` was for double-precision floating point.

`v` An Altivec vector register (VR), `v0...v31`.

`wa` A VSX register (VSR), `vs0...vs63`. This is either an FPR (`vs0...vs31` are `f0...f31`) or a VR (`vs32...vs63` are `v0...v31`).

When using `wa`, you should use the `%x` output modifier, so that the correct register number is printed. For example:

```
asm ("xvadddp %x0,%x1,%x2"
     : "=wa" (v1)
     : "wa" (v2), "wa" (v3));
```

You should not use `%x` for `v` operands:

```
asm ("xsaddqp %0,%1,%2"
     : "=v" (v1)
     : "v" (v2), "v" (v3));
```

`c` The count register, `ctr`.

`l` The link register, `lr`.

`x` Condition register field 0, `cr0`.

`y` Any condition register field, `cr0...cr7`.

`I` A signed 16-bit constant.

`J` An unsigned 16-bit constant shifted left 16 bits (use `L` instead for `SImode` constants).

`K` An unsigned 16-bit constant.

`L` A signed 16-bit constant shifted left 16 bits.

`eI` A signed 34-bit integer constant if prefixed instructions are supported.

`eP` A scalar floating point constant or a vector constant that can be loaded to a VSX register with one prefixed instruction.

`eQ` An IEEE 128-bit constant that can be loaded into a VSX register with the `lxvkq` instruction.

`m` A memory operand. Normally, `m` does not allow addresses that update the base register. If the `<` or `>` constraint is also used, they are allowed and therefore on PowerPC targets in that case it is only safe to use `m<>` in an `asm` statement if that `asm` statement accesses the operand exactly once. The `asm` statement must also use `%U`<*opno*> as a placeholder for the “update” flag in the corresponding load or store instruction. For example:

```
asm ("st%U0 %1,%0" : "=m<>" (mem) : "r" (val));
```

is correct but:

```
asm ("st %1,%0" : "=m<>" (mem) : "r" (val));
```

is not.

`Q` A memory operand addressed by just a base register.

`Z` A memory operand accessed with indexed or indirect addressing.

`a` An indexed or indirect address.

PRU—`config/pru/constraints.md`

`I` An unsigned 8-bit integer constant.

`J` An unsigned 16-bit integer constant.

`L` An unsigned 5-bit integer constant (for shift counts).

`T` A text segment (program memory) constant label.

`Z` Integer constant zero.

RL78—`config/rl78/constraints.md`

`Int3` An integer constant in the range 1 ... 7.

`Int8` An integer constant in the range 0 ... 255.

`J` An integer constant in the range −255 ... 0

`K` The integer constant 1.

`L` The integer constant -1.

`M` The integer constant 0.

`N` The integer constant 2.

`O` The integer constant -2.

`P` An integer constant in the range 1 ... 15.

`Qbi` The built-in compare types–eq, ne, gtu, ltu, geu, and leu.

`Qsc` The synthetic compare types–gt, lt, ge, and le.

`Wab` A memory reference with an absolute address.

`Wbc` A memory reference using `BC` as a base register, with an optional offset.

`Wca` A memory reference using `AX`, `BC`, `DE`, or `HL` for the address, for calls.

`Wcv` A memory reference using any 16-bit register pair for the address, for calls.

`Wd2` A memory reference using `DE` as a base register, with an optional offset.

`Wde` A memory reference using `DE` as a base register, without any offset.

`Wfr` Any memory reference to an address in the far address space.

`Wh1` A memory reference using `HL` as a base register, with an optional one-byte offset.

`Whb` A memory reference using `HL` as a base register, with `B` or `C` as the index register.

`Whl` A memory reference using `HL` as a base register, without any offset.

`Ws1` A memory reference using `SP` as a base register, with an optional one-byte offset.

`Y` Any memory reference to an address in the near address space.

`A` The `AX` register.

`B` The `BC` register.

`D` The `DE` register.

`R` `A` through `L` registers.

`S` The `SP` register.

`T` The `HL` register.

`Z08W` The 16-bit `R8` register.

`Z10W` The 16-bit `R10` register.

`Zint` The registers reserved for interrupts (`R24` to `R31`).

`a` The `A` register.

`b` The `B` register.

`c` The `C` register.

`d` The `D` register.

`e` The `E` register.

`h` The `H` register.

`l` The `L` register.

`v` The virtual registers.

`w` The `PSW` register.

`x` The `X` register.

RISC-V—`config/riscv/constraints.md`

`f` A floating-point register (if available).

`I` An I-type 12-bit signed immediate.

`J` Integer zero.

`K` A 5-bit unsigned immediate for CSR access instructions.

`A` An address that is held in a general-purpose register.

`S` A constraint that matches an absolute symbolic address.

`vr` A vector register (if available)..

`vd` A vector register, excluding v0 (if available).

`vm` A vector register, only v0 (if available).

`cr` RVC general purpose register (x8-x15).

`cf` RVC floating-point registers (f8-f15), if available, reuse GPR as FPR when use zfinx.

`cR` Even-odd RVC general purpose register pair.

`R` Even-odd general purpose register pair.

RX—`config/rx/constraints.md`

`Q` An address which does not involve register indirect addressing or pre/post increment/decrement addressing.

`Symbol` A symbol reference.

`Int08` A constant in the range −256 to 255, inclusive.

`Sint08` A constant in the range −128 to 127, inclusive.

`Sint16` A constant in the range −32768 to 32767, inclusive.

`Sint24` A constant in the range −8388608 to 8388607, inclusive.

`Uint04` A constant in the range 0 to 15, inclusive.

S/390 and zSeries—`config/s390/s390.h`

`a` Address register (general purpose register except r0)

`c` Condition code register

`d` Data register (arbitrary general purpose register)

`f` Floating-point register

`I` Unsigned 8-bit constant (0–255)

`J` Unsigned 12-bit constant (0–4095)

`K` Signed 16-bit constant (−32768–32767)

`L` Value appropriate as displacement.

`(0..4095)`
for short displacement

`(−524288..524287)`
for long displacement

`M` Constant integer with a value of 0x7fffffff.

`N` Multiple letter constraint followed by 4 parameter letters.

`0..9:` number of the part counting from most to least significant

`H,Q:` mode of the part

`D,S,H:` mode of the containing operand

`0,F:` value of the other parts (F—all bits set)

The constraint matches if the specified part of a constant has a value different from its other parts.

`Q` Memory reference without index register and with short displacement.

`R` Memory reference with index register and short displacement.

`S` Memory reference without index register but with long displacement.

`T` Memory reference with index register and long displacement.

`U` Pointer with short displacement.

`W` Pointer with long displacement.

`Y` Shift count operand.

SPARC—`config/sparc/sparc.h`

`f` Floating-point register on the SPARC-V8 architecture and lower floating-point register on the SPARC-V9 architecture.

`e` Floating-point register. It is equivalent to '`f`' on the SPARC-V8 architecture and contains both lower and upper floating-point registers on the SPARC-V9 architecture.

`c` Floating-point condition code register.

`d` Lower floating-point register. It is only valid on the SPARC-V9 architecture when the Visual Instruction Set is available.

`b` Floating-point register. It is only valid on the SPARC-V9 architecture when the Visual Instruction Set is available.

`h` 64-bit global or out register for the SPARC-V8+ architecture.

`C` The constant all-ones, for floating-point.

`A` Signed 5-bit constant

`D` A vector constant

`I` Signed 13-bit constant

`J` Zero

`K` 32-bit constant with the low 12 bits clear (a constant that can be loaded with the `sethi` instruction)

`L` A constant in the range supported by `movcc` instructions (11-bit signed immediate)

`M` A constant in the range supported by `movrcc` instructions (10-bit signed immediate)

`N` Same as '`K`', except that it verifies that bits that are not in the lower 32-bit range are all zero. Must be used instead of '`K`' for modes wider than `SImode`

`O` The constant 4096

`G` Floating-point zero

`H` Signed 13-bit constant, sign-extended to 32 or 64 bits

`P` The constant -1

`Q` Floating-point constant whose integral representation can be moved into an integer register using a single sethi instruction

`R` Floating-point constant whose integral representation can be moved into an integer register using a single mov instruction

`S` Floating-point constant whose integral representation can be moved into an integer register using a high/lo_sum instruction sequence

`T` Memory address aligned to an 8-byte boundary

`W` Memory address for '`e`' constraint registers

`w` Memory address with only a base register

`Y` Vector zero

TI C6X family—`config/c6x/constraints.md`

`a` Register file A (A0–A31).

`b` Register file B (B0–B31).

`A` Predicate registers in register file A (A0–A2 on C64X and higher, A1 and A2 otherwise).

`B` Predicate registers in register file B (B0–B2).

`C` A call-used register in register file B (B0–B9, B16–B31).

`Da` Register file A, excluding predicate registers (A3–A31, plus A0 if not C64X or higher).

`Db` Register file B, excluding predicate registers (B3–B31).

`Iu4` Integer constant in the range 0 ... 15.

`Iu5` Integer constant in the range 0 ... 31.

`In5` Integer constant in the range −31 ... 0.

`Is5` Integer constant in the range −16 ... 15.

`I5x` Integer constant that can be the operand of an ADDA or a SUBA insn.

`IuB` Integer constant in the range 0 ... 65535.

`IsB` Integer constant in the range −32768 ... 32767.

`IsC` Integer constant in the range $-2^{20} \ldots 2^{20} - 1$.

`Jc` Integer constant that is a valid mask for the clr instruction.

`Js` Integer constant that is a valid mask for the set instruction.

`Q` Memory location with A base register.

`R` Memory location with B base register.

`Z` Register B14 (aka DP).

Visium—`config/visium/constraints.md`

`b` EAM register `mdb`

`c` EAM register `mdc`

`f` Floating point register

`l` General register, but not `r29`, `r30` and `r31`

`t` Register `r1`

`u` Register `r2`

`v` Register `r3`

`G` Floating-point constant 0.0

`J` Integer constant in the range 0 .. 65535 (16-bit immediate)

`K` Integer constant in the range 1 .. 31 (5-bit immediate)

`L` Integer constant in the range −65535 .. −1 (16-bit negative immediate)

`M` Integer constant −1

`O` Integer constant 0

`P` Integer constant 32

x86 family—`config/i386/constraints.md`

`R` Legacy register—the eight integer registers available on all i386 processors (`a`, `b`, `c`, `d`, `si`, `di`, `bp`, `sp`).

`q` Any register accessible as `rl`. In 32-bit mode, `a`, `b`, `c`, and `d`; in 64-bit mode, any integer register.

`Q` Any register accessible as `rh`: `a`, `b`, `c`, and `d`.

`a` The `a` register.

`b` The `b` register.

`c` The `c` register.

`d` The `d` register.

`S` The `si` register.

`D` The `di` register.

`A` The `a` and `d` registers. This class is used for instructions that return double word results in the `ax:dx` register pair. Single word values will be allocated either in `ax` or `dx`. For example on i386 the following implements `rdtsc`:

```
unsigned long long rdtsc (void)
{
  unsigned long long tick;
  __asm__ __volatile__("rdtsc":"=A"(tick));
  return tick;
}
```

This is not correct on x86-64 as it would allocate tick in either `ax` or `dx`. You have to use the following variant instead:

```
unsigned long long rdtsc (void)
{
  unsigned int tickl, tickh;
  __asm__ __volatile__("rdtsc":"=a"(tickl),"=d"(tickh));
  return ((unsigned long long)tickh << 32)|tickl;
}
```

`U` The call-clobbered integer registers.

`f` Any 80387 floating-point (stack) register.

`t` Top of 80387 floating-point stack (`%st(0)`).

`u` Second from top of 80387 floating-point stack (`%st(1)`).

`y` Any MMX register.

`x` Any SSE register.

`v` Any EVEX encodable SSE register (`%xmm0-%xmm31`).

`Yz` First SSE register (`%xmm0`).

`I` Integer constant in the range 0 ... 31, for 32-bit shifts.

`J` Integer constant in the range 0 ... 63, for 64-bit shifts.

`K` Signed 8-bit integer constant.

`L` `0xFF` or `0xFFFF`, for andsi as a zero-extending move.

`M` 0, 1, 2, or 3 (shifts for the `lea` instruction).

`N` Unsigned 8-bit integer constant (for `in` and `out` instructions).

`G` Standard 80387 floating point constant.

`C` SSE constant zero operand.

`e` 32-bit signed integer constant, or a symbolic reference known to fit that range (for immediate operands in sign-extending x86-64 instructions).

`We` 32-bit signed integer constant, or a symbolic reference known to fit that range (for sign-extending conversion operations that require non-`VOIDmode` immediate operands).

`Wz` 32-bit unsigned integer constant, or a symbolic reference known to fit that range (for zero-extending conversion operations that require non-`VOIDmode` immediate operands).

`Wd` 128-bit integer constant where both the high and low 64-bit word satisfy the `e` constraint.

`Ws` A symbolic reference or label reference. You can use the `%p` modifier to print the raw symbol.

`Z` 32-bit unsigned integer constant, or a symbolic reference known to fit that range (for immediate operands in zero-extending x86-64 instructions).

`Tv` VSIB address operand.

`Ts` Address operand without segment register.

Xstormy16—`config/stormy16/stormy16.h`

`a` Register r0.

`b` Register r1.

`c` Register r2.

`d` Register r8.

`e` Registers r0 through r7.

`t` Registers r0 and r1.

`y` The carry register.

`z` Registers r8 and r9.

`I` A constant between 0 and 3 inclusive.

`J` A constant that has exactly one bit set.

`K` A constant that has exactly one bit clear.

`L` A constant between 0 and 255 inclusive.

`M` A constant between −255 and 0 inclusive.

`N` A constant between −3 and 0 inclusive.

`O` A constant between 1 and 4 inclusive.

`P` A constant between −4 and −1 inclusive.

`Q` A memory reference that is a stack push.

`R` A memory reference that is a stack pop.

`S` A memory reference that refers to a constant address of known value.

`T` The register indicated by Rx (not implemented yet).

`U` A constant that is not between 2 and 15 inclusive.

`Z` The constant 0.

Xtensa—`config/xtensa/constraints.md`

`a` General-purpose 32-bit register

`b` One-bit boolean register

`A` MAC16 40-bit accumulator register

`I` Signed 12-bit integer constant, for use in MOVI instructions

`J` Signed 8-bit integer constant, for use in ADDI instructions

`K` Integer constant valid for BccI instructions

`L` Unsigned constant valid for BccUI instructions

6.11.4 C++11 Constant Expressions instead of String Literals

In C++ with `-std=gnu++11` or later, strings that appear in asm syntax—specifically, the assembler template, constraints, and clobbers—can be specified as parenthesized compile-time constant expressions as well as by string literals. The parentheses around such an expression are a required part of the syntax. The constant expression can return a container with `data ()` and `size ()` member functions, following similar rules as the C++26 `static_assert` message. Any string is converted to the character set of the source code. When this feature is available the `__GXX_CONSTEXPR_ASM__` preprocessor macro is predefined.

This extension is supported for both the basic and extended asm syntax.

```
#include <string>
constexpr std::string_view genfoo() { return "foo"; }

void function()
{
  asm((genfoo()));
}
```

6.11.5 Controlling Names Used in Assembler Code

You can specify the name to be used in the assembler code for a C function or variable by writing the `asm` (or `__asm__`) keyword after the declarator. It is up to you to make sure that the assembler names you choose do not conflict with any other assembler symbols, or reference registers.

Assembler names for data

This sample shows how to specify the assembler name for data:

```
int foo asm ("myfoo") = 2;
```

This specifies that the name to be used for the variable `foo` in the assembler code should be '`myfoo`' rather than the usual '`_foo`'.

On systems where an underscore is normally prepended to the name of a C variable, this feature allows you to define names for the linker that do not start with an underscore.

GCC does not support using this feature with a non-static local variable since such variables do not have assembler names. If you are trying to put the variable in a particular register, see Section 6.11.6 [Explicit Register Variables], page 807.

Assembler names for functions

To specify the assembler name for functions, write a declaration for the function before its definition and put `asm` there, like this:

```
int func (int x, int y) asm ("MYFUNC");

int func (int x, int y)
{
   /* ... */
```

This specifies that the name to be used for the function `func` in the assembler code should be `MYFUNC`.

6.11.6 Variables in Specified Registers

GNU C allows you to associate specific hardware registers with C variables. In almost all cases, allowing the compiler to assign registers produces the best code. However under certain unusual circumstances, more precise control over the variable storage is required.

Both global and local variables can be associated with a register. The consequences of performing this association are very different between the two, as explained in the sections below.

6.11.6.1 Defining Global Register Variables

You can define a global register variable and associate it with a specified register like this:

```
register int *foo asm ("r12");
```

Here `r12` is the name of the register that should be used. Note that this is the same syntax used for defining local register variables, but for a global variable the declaration appears outside a function. The `register` keyword is required, and cannot be combined with `static`. The register name must be a valid register name for the target platform.

Do not use type qualifiers such as `const` and `volatile`, as the outcome may be contrary to expectations. In particular, using the `volatile` qualifier does not fully prevent the compiler from optimizing accesses to the register.

Registers are a scarce resource on most systems and allowing the compiler to manage their usage usually results in the best code. However, under special circumstances it can make sense to reserve some globally. For example this may be useful in programs such as programming language interpreters that have a couple of global variables that are accessed very often.

After defining a global register variable, for the current compilation unit:

- If the register is a call-saved register, call ABI is affected: the register will not be restored in function epilogue sequences after the variable has been assigned. Therefore, functions cannot safely return to callers that assume standard ABI.
- Conversely, if the register is a call-clobbered register, making calls to functions that use standard ABI may lose contents of the variable. Such calls may be created by the compiler even if none are evident in the original program, for example when libgcc functions are used to make up for unavailable instructions.
- Accesses to the variable may be optimized as usual and the register remains available for allocation and use in any computations, provided that observable values of the variable are not affected.

- If the variable is referenced in inline assembly, the type of access must be provided to the compiler via constraints (see Section 6.11.3 [Constraints], page 776). Accesses from basic asms are not supported.

Note that these points *only* apply to code that is compiled with the definition. The behavior of code that is merely linked in (for example code from libraries) is not affected.

If you want to recompile source files that do not actually use your global register variable so they do not use the specified register for any other purpose, you need not actually add the global register declaration to their source code. It suffices to specify the compiler option `-ffixed-reg` (see Section 3.18 [Code Gen Options], page 315) to reserve the register.

Declaring the variable

Global register variables cannot have initial values, because an executable file has no means to supply initial contents for a register.

When selecting a register, choose one that is normally saved and restored by function calls on your machine. This ensures that code which is unaware of this reservation (such as library routines) will restore it before returning.

On machines with register windows, be sure to choose a global register that is not affected magically by the function call mechanism.

Using the variable

When calling routines that are not aware of the reservation, be cautious if those routines call back into code which uses them. As an example, if you call the system library version of `qsort`, it may clobber your registers during execution, but (if you have selected appropriate registers) it will restore them before returning. However it will *not* restore them before calling `qsort`'s comparison function. As a result, global values will not reliably be available to the comparison function unless the `qsort` function itself is rebuilt.

Similarly, it is not safe to access the global register variables from signal handlers or from more than one thread of control. Unless you recompile them specially for the task at hand, the system library routines may temporarily use the register for other things. Furthermore, since the register is not reserved exclusively for the variable, accessing it from handlers of asynchronous signals may observe unrelated temporary values residing in the register.

On most machines, `longjmp` restores to each global register variable the value it had at the time of the `setjmp`. On some machines, however, `longjmp` does not change the value of global register variables. To be portable, the function that called `setjmp` should make other arrangements to save the values of the global register variables, and to restore them in a `longjmp`. This way, the same thing happens regardless of what `longjmp` does.

6.11.6.2 Specifying Registers for Local Variables

You can define a local register variable and associate it with a specified register like this:

```
register int *foo asm ("r12");
```

Here `r12` is the name of the register that should be used. Note that this is the same syntax used for defining global register variables, but for a local variable the declaration appears within a function. The `register` keyword is required, and cannot be combined with `static`. The register name must be a valid register name for the target platform.

Do not use type qualifiers such as `const` and `volatile`, as the outcome may be contrary to expectations. In particular, when the `const` qualifier is used, the compiler may substitute the variable with its initializer in `asm` statements, which may cause the corresponding operand to appear in a different register.

As with global register variables, it is recommended that you choose a register that is normally saved and restored by function calls on your machine, so that calls to library routines will not clobber it.

The only supported use for this feature is to specify registers for input and output operands when calling Extended `asm` (see Section 6.11.2 [Extended Asm], page 754). This may be necessary if the constraints for a particular machine don't provide sufficient control to select the desired register. To force an operand into a register, create a local variable and specify the register name after the variable's declaration. Then use the local variable for the `asm` operand and specify any constraint letter that matches the register:

```
register int *p1 asm ("r0") = ...;
register int *p2 asm ("r1") = ...;
register int *result asm ("r0");
asm ("sysint" : "=r" (result) : "0" (p1), "r" (p2));
```

Warning: In the above example, be aware that a register (for example `r0`) can be call-clobbered by subsequent code, including function calls and library calls for arithmetic operators on other variables (for example the initialization of `p2`). In this case, use temporary variables for expressions between the register assignments:

```
int t1 = ...;
register int *p1 asm ("r0") = ...;
register int *p2 asm ("r1") = t1;
register int *result asm ("r0");
asm ("sysint" : "=r" (result) : "0" (p1), "r" (p2));
```

Defining a register variable does not reserve the register. Other than when invoking the Extended `asm`, the contents of the specified register are not guaranteed. For this reason, the following uses are explicitly *not* supported. If they appear to work, it is only happenstance, and may stop working as intended due to (seemingly) unrelated changes in surrounding code, or even minor changes in the optimization of a future version of gcc:

- Passing parameters to or from Basic `asm`
- Passing parameters to or from Extended `asm` without using input or output operands.
- Passing parameters to or from routines written in assembler (or other languages) using non-standard calling conventions.

Some developers use Local Register Variables in an attempt to improve gcc's allocation of registers, especially in large functions. In this case the register name is essentially a hint to the register allocator. While in some instances this can generate better code, improvements are subject to the whims of the allocator/optimizers. Since there are no guarantees that your improvements won't be lost, this usage of Local Register Variables is discouraged.

On the MIPS platform, there is related use for local register variables with slightly different characteristics (see Section "Defining coprocessor specifics for MIPS targets" in *GNU Compiler Collection (GCC) Internals*).

6.11.6.3 Hard Register Constraints

Similar to register `asm` but still distinct, hard register constraints are another way to force operands of inline `asm` into specific machine registers. In contrast to register `asm` where a variable is bound to a machine register, a hard register constraint binds an `asm` operand to a machine register. Assume in the following that `r4` is a general-purpose register, `f5` a floating-point register, and `v6` a vector register for some target.

```
int x;
int y __attribute__ ((vector_size (16)));
...
asm ("some instructions"
     : "={r4}" (x)
     : "{f5}" (42.0), "{v6}" (y));
```

For the inline `asm`, variable `x` is bound to register `r4`, and `y` is loaded to `v6`. Furthermore, constant `42.0` is loaded into floating-point register `f5`.

A key difference between register `asm` and hard register constraints is that the latter are specified at the point where they are supposed to materialize, namely at inline `asm`, which may lead to more readable code.

Usage

Each input operand is loaded into the register specified by its corresponding hard register constraint. Furthermore, each hard register must be used at most once among an alternative for inputs. This renders hard register constraints more strict compared to register `asm` where multiple inputs may share a register as for example in

```
int x;
register int y asm ("0") = ...;
asm ("" : "=r" (x) : "r" (y), "r" (y));
```

or even

```
register int x asm ("0") = 42;
register int y asm ("0") = 24;
asm ("" : "=r" (x) : "r" (x), "r" (y));
```

The analogue for hard register constraints is invalid in order to prevent subtle bugs.

Likewise, two outputs must not share a register among an alternative. That means, the following example is invalid

```
int x, y;
asm ("" : "={r4}" (x), "={r4}" (y));  // invalid
```

which also aligns with register `asm`. Despite that, each output must refer to a distinct object if a hard register constraint is involved. For example, in the following, object `x` is assigned two registers.

```
int x;
asm ("" : "=r" (x), "=r" (x));
```

This is not allowed for hard register constraints in order to prevent subtle bugs. Even if only one output operand has a hard register constraint, the code is rejected since the allocation for the object is still ambiguous.

```
int x;
asm ("" : "=r" (x), "={1}" (x));  // invalid
```

The type of an operand must be supported by the corresponding machine register.

A hard register constraint may refer to any general, floating-point, or vector register except a fixed register as e.g. the stack-pointer register. The set of allowed registers is target dependent analogue to register `asm`. Furthermore, the referenced register must be a valid register name of the target. Note, on some targets, a single register may be referred to by different names where each name specifies the length of the register. For example, on x86_64 the register names `rcx`, `ecx`, and `cx` all refer to the same register but in different sizes. If any of those names is used for a hard register constraint, the actual size of a register is determined by its corresponding operand. For example

```
long x;
asm ("mov\t$42, %0" : "={ecx}" (x));
```

Although the hard register constraint refers to register `ecx`, the actual register will be `rcx` since on x86_64 a `long` is 8 byte in total. This aligns with register `asm` where you could have

```
register long x asm ("ecx");
```

Interaction with Register asm

A mixture of both constructs as for example

```
register int x asm ("r4") = 42;
int y;
asm ("" : "={r5}" (y) : "r" (x));
```

is valid.

If an operand is a register `asm` and the corresponding constraint a hard register, then both must refer to the same register. That means

```
register int x asm ("r4");
asm ("" : "={r4}" (x));
```

is valid and

```
register int x asm ("r4");
asm ("" : "={r5}" (x));  // invalid
```

is invalid.

Note, register `asm` may not only be clobbered by function calls but also by inline `asm` in conjunction with hard register constraints. For example, in the following

```
register int x asm ("r5") = 42;
int y;
asm ("" : "={r5}" (y));
asm ("" : "+r" (x));
```

variable `x` materializes before the very first inline `asm` which writes to register `r5` and therefore clobbers `x` which in turn is read by the subsequent inline `asm`.

Limitations

At the moment fixed registers are not supported for hard register constraints. Thus, idioms like

```
register void *x asm ("rsp");
asm ("" : "=r" (x));
```

are not supported for hard register constraints. This might be lifted.

6.11.7 Size of an asm

Some targets require that GCC track the size of each instruction used in order to generate correct code. Because the final length of the code produced by an `asm` statement is only known by the assembler, GCC must make an estimate as to how big it will be. It does this by counting the number of instructions in the pattern of the `asm` and multiplying that by the length of the longest instruction supported by that processor. (When working out the number of instructions, it assumes that any occurrence of a newline or of whatever statement separator character is supported by the assembler — typically ‘;’ — indicates the end of an instruction.)

Normally, GCC’s estimate is adequate to ensure that correct code is generated, but it is possible to confuse the compiler if you use pseudo instructions or assembler macros that expand into multiple real instructions, or if you use assembler directives that expand to more space in the object file than is needed for a single instruction. If this happens then the assembler may produce a diagnostic saying that a label is unreachable.

This size is also used for inlining decisions. If you use `asm inline` instead of just `asm`, then for inlining purposes the size of the asm is taken as the minimum size, ignoring how many instructions GCC thinks it is.

6.12 Other Extensions to C Syntax

GNU C has traditionally supported numerous extensions to standard C syntax. Some of these features were originally intended for compatibility with other compilers or to ease traditional C compatibility, some have been adopted into subsequent versions of the C and/or C++ standards, while others remain specific to GNU C.

6.12.1 Statements and Declarations in Expressions

A compound statement enclosed in parentheses may appear as an expression in GNU C. This allows you to use loops, switches, and local variables within an expression.

Recall that a compound statement is a sequence of statements surrounded by braces; in this construct, parentheses go around the braces. For example:

```
({ int y = foo (); int z;
   if (y > 0) z = y;
   else z = - y;
   z; })
```

is a valid (though slightly more complex than necessary) expression for the absolute value of `foo ()`.

The last thing in the compound statement should be an expression followed by a semicolon; the value of this subexpression serves as the value of the entire construct. (If you use some other kind of statement last within the braces, the construct has type `void`, and thus effectively no value.)

This feature is especially useful in making macro definitions “safe” (so that they evaluate each operand exactly once). For example, the “maximum” function is commonly defined as a macro in standard C as follows:

```
#define max(a,b) ((a) > (b) ? (a) : (b))
```

But this definition computes either *a* or *b* twice, with bad results if the operand has side effects. In GNU C, if you know the type of the operands (here taken as `int`), you can avoid this problem by defining the macro as follows:

```
#define maxint(a,b) \
  ({int _a = (a), _b = (b); _a > _b ? _a : _b; })
```

Note that introducing variable declarations (as we do in `maxint`) can cause variable shadowing, so while this example using the `max` macro produces correct results:

```
int _a = 1, _b = 2, c;
```

```
c = max (_a, _b);
```

this example using maxint will not:

```
int _a = 1, _b = 2, c;
c = maxint (_a, _b);
```

This problem may for instance occur when we use this pattern recursively, like so:

```
#define maxint3(a, b, c) \
  ({int _a = (a), _b = (b), _c = (c); maxint (maxint (_a, _b), _c); })
```

Embedded statements are not allowed in constant expressions, such as the value of an enumeration constant, the width of a bit-field, or the initial value of a static variable.

If you don't know the type of the operand, you can still do this, but you must use `typeof` or `__auto_type` (see Section 6.12.5 [Typeof], page 818).

In G++, the result value of a statement expression undergoes array and function pointer decay, and is returned by value to the enclosing expression. For instance, if `A` is a class, then

```
        A a;

        ({a;}).Foo ()
```

constructs a temporary `A` object to hold the result of the statement expression, and that is used to invoke `Foo`. Therefore the `this` pointer observed by `Foo` is not the address of `a`.

In a statement expression, any temporaries created within a statement are destroyed at that statement's end. This makes statement expressions inside macros slightly different from function calls. In the latter case temporaries introduced during argument evaluation are destroyed at the end of the statement that includes the function call. In the statement expression case they are destroyed during the statement expression. For instance,

```
#define macro(a)  ({__typeof__(a) b = (a); b + 3; })
template<typename T> T function(T a) { T b = a; return b + 3; }

void foo ()
{
  macro (X ());
  function (X ());
}
```

has different places where temporaries are destroyed. For the `macro` case, the temporary `X` is destroyed just after the initialization of `b`. In the `function` case that temporary is destroyed when the function returns.

These considerations mean that it is probably a bad idea to use statement expressions of this form in header files that are designed to work with C++. (Note that some versions of the GNU C Library contained header files using statement expressions that lead to precisely this bug.)

Jumping into a statement expression with `goto` or using a `switch` statement outside the statement expression with a `case` or `default` label inside the statement expression is not permitted. Jumping into a statement expression with a computed `goto` (see Section 6.12.3 [Labels as Values], page 815) has undefined behavior. Jumping out of a statement expression is permitted, but if the statement expression is part of a larger expression then it is unspecified which other subexpressions of that expression have been evaluated except where the language definition requires certain subexpressions to be evaluated before or after the statement expression. A `break` or `continue` statement inside of a statement expression used in `while`, `do` or `for` loop or `switch` statement condition or `for` statement init or increment expressions jumps to an outer loop or `switch` statement if any (otherwise it is an error), rather than to the loop or `switch` statement in whose condition or init or increment expression it appears. In any case, as with a function call, the evaluation of a statement expression is not interleaved with the evaluation of other parts of the containing expression. For example,

```
foo (), (({ bar1 (); goto a; 0; }) + bar2 ()), baz();
```

calls `foo` and `bar1` and does not call `baz` but may or may not call `bar2`. If `bar2` is called, it is called after `foo` and before `bar1`.

6.12.2 Locally Declared Labels

GCC allows you to declare *local labels* in any nested block scope. A local label is just like an ordinary label, but you can only reference it (with a `goto` statement, or by taking its address) within the block in which it is declared.

A local label declaration looks like this:

```
__label__ label;
```

or

```
__label__ label1, label2, /* ... */;
```

Local label declarations must come at the beginning of the block, before any ordinary declarations or statements.

The label declaration defines the label *name*, but does not define the label itself. You must do this in the usual way, with `label:`, within the statements of the statement expression.

The local label feature is useful for complex macros. If a macro contains nested loops, a `goto` can be useful for breaking out of them. However, an ordinary label whose scope is the whole function cannot be used: if the macro can be expanded several times in one function, the label is multiply defined in that function. A local label avoids this problem. For example:

```
#define SEARCH(value, array, target)              \
do {                                              \
  __label__ found;                                \
  typeof (target) _SEARCH_target = (target);      \
  typeof (*(array)) *_SEARCH_array = (array);     \
  int i, j;                                       \
  int value;                                      \
  for (i = 0; i < max; i++)                       \
    for (j = 0; j < max; j++)                     \
      if (_SEARCH_array[i][j] == _SEARCH_target)  \
        { (value) = i; goto found; }              \
  (value) = -1;                                   \
 found:;                                          \
} while (0)
```

This could also be written using a statement expression:

```
#define SEARCH(array, target)                     \
({                                                \
  __label__ found;                                \
  typeof (target) _SEARCH_target = (target);      \
  typeof (*(array)) *_SEARCH_array = (array);     \
  int i, j;                                       \
  int value;                                      \
```

```
    for (i = 0; i < max; i++)                      \
      for (j = 0; j < max; j++)                    \
        if (_SEARCH_array[i][j] == _SEARCH_target)  \
          { value = i; goto found; }               \
    value = -1;                                    \
   found:                                          \
    value;                                         \
  })
```

Local label declarations also make the labels they declare visible to nested functions, if there are any. See Section 6.12.4 [Nested Functions], page 816, for details.

6.12.3 Labels as Values

You can get the address of a label defined in the current function (or a containing function) with the unary operator '`&&`'. The value has type `void *`. This value is a constant and can be used wherever a constant of that type is valid. For example:

```
void *ptr;
/* ... */
ptr = &&foo;
```

To use these values, you need to be able to jump to one. This is done with the computed goto statement[2], `goto *exp;`. For example,

```
goto *ptr;
```

Any expression of type `void *` is allowed.

One way of using these constants is in initializing a static array that serves as a jump table:

```
static void *array[] = { &&foo, &&bar, &&hack };
```

Then you can select a label with indexing, like this:

```
goto *array[i];
```

Note that this does not check whether the subscript is in bounds—array indexing in C never does that.

Such an array of label values serves a purpose much like that of the `switch` statement. The `switch` statement is cleaner, so use that rather than an array unless the problem does not fit a `switch` statement very well.

Another use of label values is in an interpreter for threaded code. The labels within the interpreter function can be stored in the threaded code for super-fast dispatching.

You may not use this mechanism to jump to code in a different function. If you do that, totally unpredictable things happen. The best way to avoid this is to store the label address only in automatic variables and never pass it as an argument.

An alternate way to write the above example is

```
static const int array[] = { &&foo - &&foo, &&bar - &&foo,
                             &&hack - &&foo };
goto *(&&foo + array[i]);
```

This is more friendly to code living in shared libraries, as it reduces the number of dynamic relocations that are needed, and by consequence, allows the data to be read-only. This

[2] The analogous feature in Fortran is called an assigned goto, but that name seems inappropriate in C, where one can do more than simply store label addresses in label variables.

alternative with label differences is not supported for the AVR target, please use the first approach for AVR programs.

The `&&foo` expressions for the same label might have different values if the containing function is inlined or cloned. If a program relies on them being always the same, `__attribute__((__noinline__,__noclone__))` should be used to prevent inlining and cloning. If `&&foo` is used in a static variable initializer, inlining and cloning is forbidden.

Unlike a normal goto, in GNU C++ a computed goto will not call destructors for objects that go out of scope.

6.12.4 Nested Functions

A *nested function* is a function defined inside another function. Nested functions are supported as an extension in GNU C, but are not supported by GNU C++.

The nested function's name is local to the block where it is defined. For example, here we define a nested function named `square`, and call it twice:

```
foo (double a, double b)
{
  double square (double z) { return z * z; }

  return square (a) + square (b);
}
```

The nested function can access all the variables of the containing function that are visible at the point of its definition. This is called *lexical scoping*. For example, here we show a nested function which uses an inherited variable named `offset`:

```
bar (int *array, int offset, int size)
{
  int access (int *array, int index)
    { return array[index + offset]; }
  int i;
  /* ... */
  for (i = 0; i < size; i++)
    /* ... */ access (array, i) /* ... */
}
```

Nested function definitions are permitted within functions in the places where variable definitions are allowed; that is, in any block, mixed with the other declarations and statements in the block.

It is possible to call the nested function from outside the scope of its name by storing its address or passing the address to another function:

```
hack (int *array, int size)
{
  void store (int index, int value)
    { array[index] = value; }

  intermediate (store, size);
}
```

Here, the function `intermediate` receives the address of `store` as an argument. If `intermediate` calls `store`, the arguments given to `store` are used to store into `array`. But this technique works only so long as the containing function (`hack`, in this example) does not exit.

If you try to call the nested function through its address after the containing function exits, all hell breaks loose. If you try to call it after a containing scope level exits, and if it refers to some of the variables that are no longer in scope, you may be lucky, but it's not wise to take the risk. If, however, the nested function does not refer to anything that has gone out of scope, you should be safe.

GCC implements taking the address of a nested function using a technique called *trampolines*. This technique was described in *Lexical Closures for C++* (Thomas M. Breuel, USENIX C++ Conference Proceedings, October 17-21, 1988).

A nested function can jump to a label inherited from a containing function, provided the label is explicitly declared in the containing function (see Section 6.12.2 [Local Labels], page 814). Such a jump returns instantly to the containing function, exiting the nested function that did the `goto` and any intermediate functions as well. Here is an example:

```
bar (int *array, int offset, int size)
{
  __label__ failure;
  int access (int *array, int index)
    {
      if (index > size)
        goto failure;
      return array[index + offset];
    }
  int i;
  /* ... */
  for (i = 0; i < size; i++)
    /* ... */ access (array, i) /* ... */
  /* ... */
  return 0;

 /* Control comes here from access
    if it detects an error.  */
 failure:
  return -1;
}
```

A nested function always has no linkage. Declaring one with `extern` or `static` is erroneous. If you need to declare the nested function before its definition, use `auto` (which is otherwise meaningless for function declarations).

```
bar (int *array, int offset, int size)
{
  __label__ failure;
  auto int access (int *, int);
  /* ... */
  int access (int *array, int index)
    {
      if (index > size)
        goto failure;
      return array[index + offset];
    }
  /* ... */
}
```

6.12.5 Referring to a Type with `typeof`

Another way to refer to the type of an expression is with `typeof`. The syntax of using of this keyword looks like `sizeof`, but the construct acts semantically like a type name defined with `typedef`.

There are two ways of writing the argument to `typeof`: with an expression or with a type. Here is an example with an expression:

```
typeof (x[0](1))
```

This assumes that `x` is an array of pointers to functions; the type described is that of the values of the functions.

Here is an example with a typename as the argument:

```
typeof (int *)
```

Here the type described is that of pointers to `int`.

If you are writing a header file that must work when included in ISO C programs, write `__typeof__` instead of `typeof`. See Section 6.12.23 [Alternate Keywords], page 824.

A `typeof` construct can be used anywhere a typedef name can be used. For example, you can use it in a declaration, in a cast, or inside of `sizeof` or `typeof`.

The operand of `typeof` is evaluated for its side effects if and only if it is an expression of variably modified type or the name of such a type.

`typeof` is often useful in conjunction with statement expressions (see Section 6.12.1 [Statement Exprs], page 812). Here is how the two together can be used to define a safe "maximum" macro which operates on any arithmetic type and evaluates each of its arguments exactly once:

```
#define max(a,b) \
  ({ typeof (a) _a = (a); \
      typeof (b) _b = (b); \
    _a > _b ? _a : _b; })
```

The reason for using names that start with underscores for the local variables is to avoid conflicts with variable names that occur within the expressions that are substituted for `a` and `b`. Eventually we hope to design a new form of declaration syntax that allows you to declare variables whose scopes start only after their initializers; this will be a more reliable way to prevent such conflicts.

Some more examples of the use of `typeof`:

- This declares `y` with the type of what `x` points to.

  ```
  typeof (*x) y;
  ```

- This declares `y` as an array of such values.

  ```
  typeof (*x) y[4];
  ```

- This declares `y` as an array of pointers to characters:

  ```
  typeof (typeof (char *)[4]) y;
  ```

  It is equivalent to the following traditional C declaration:

  ```
  char *y[4];
  ```

  To see the meaning of the declaration using `typeof`, and why it might be a useful way to write, rewrite it with these macros:

  ```
  #define pointer(T)  typeof(T *)
  #define array(T, N) typeof(T [N])
  ```

Now the declaration can be rewritten this way:

```
array (pointer (char), 4) y;
```

Thus, `array (pointer (char), 4)` is the type of arrays of 4 pointers to `char`.

The ISO C23 operator `typeof_unqual` is available in ISO C23 mode and its result is the non-atomic unqualified version of what `typeof` operator returns. Alternate spelling `__typeof_unqual__` is available in all C modes and provides non-atomic unqualified version of what `__typeof__` operator returns. See Section 6.12.23 [Alternate Keywords], page 824.

In GNU C, but not GNU C++, you may also declare the type of a variable as `__auto_type`. In that case, the declaration must declare only one variable, whose declarator must just be an identifier, the declaration must be initialized, and the type of the variable is determined by the initializer; the name of the variable is not in scope until after the initializer. (In C++, you should use C++11 `auto` for this purpose.) Using `__auto_type`, the "maximum" macro above could be written as:

```
#define max(a,b) \
  ({ __auto_type _a = (a); \
      __auto_type _b = (b); \
    _a > _b ? _a : _b; })
```

Using `__auto_type` instead of `typeof` has two advantages:

- Each argument to the macro appears only once in the expansion of the macro. This prevents the size of the macro expansion growing exponentially when calls to such macros are nested inside arguments of such macros.
- If the argument to the macro has variably modified type, it is evaluated only once when using `__auto_type`, but twice if `typeof` is used.

6.12.6 Determining the Number of Elements of Arrays

The keyword `_Countof` determines the number of elements of an array operand. Its syntax is similar to `sizeof`. The operand must be a parenthesized complete array type name or an expression of such a type. For example:

```
int a[n];
_Countof (a);  // returns n
_Countof (int [7][3]);  // returns 7
```

The result of this operator is an integer constant expression, unless the array has a variable number of elements. The operand is only evaluated if the array has a variable number of elements. For example:

```
_Countof (int [7][n++]);  // integer constant expression
_Countof (int [n++][7]);  // run-time value; n++ is evaluated
```

6.12.7 The maximum and minimum representable values of a type

The keywords `_Maxof` and `_Minof` determine the maximum and minimum representable values of an integer type. Their syntax is similar to `sizeof`. The operand must be a parenthesized integer type. The result of these operators is an integer constant expression of the same type as the operand. For example:

```
_Maxof (int);    // returns '(int) INT_MAX'
_Minof (short);  // returns '(short) SHRT_MIN'
```

6.12.8 Support for `offsetof`

GCC implements for both C and C++ a syntactic extension to implement the `offsetof` macro.

```
primary:
        "__builtin_offsetof" "(" typename "," offsetof_member_designator ")"

offsetof_member_designator:
          identifier
        | offsetof_member_designator "." identifier
        | offsetof_member_designator "[" expr "]"
```

This extension is sufficient such that

```
#define offsetof(type, member)  __builtin_offsetof (type, member)
```

is a suitable definition of the `offsetof` macro. In C++, *type* may be dependent. In either case, *member* may consist of a single identifier, or a sequence of member accesses and array references.

6.12.9 Determining the Alignment of Functions, Types or Variables

The keyword `__alignof__` determines the alignment requirement of a function, object, or a type, or the minimum alignment usually required by a type. Its syntax is just like `sizeof` and C11 `_Alignof`.

For example, if the target machine requires a `double` value to be aligned on an 8-byte boundary, then `__alignof__ (double)` is 8. This is true on many RISC machines. On more traditional machine designs, `__alignof__ (double)` is 4 or even 2.

Some machines never actually require alignment; they allow references to any data type even at an odd address. For these machines, `__alignof__` reports the smallest alignment that GCC gives the data type, usually as mandated by the target ABI.

If the operand of `__alignof__` is an lvalue rather than a type, its value is the required alignment for its type, taking into account any minimum alignment specified by attribute `aligned` (see Section 6.4.2.1 [Common Variable Attributes], page 699). For example, after this declaration:

```
struct foo { int x; char y; } foo1;
```

the value of `__alignof__ (foo1.y)` is 1, even though its actual alignment is probably 2 or 4, the same as `__alignof__ (int)`. It is an error to ask for the alignment of an incomplete type other than `void`.

If the operand of the `__alignof__` expression is a function, the expression evaluates to the alignment of the function which may be specified by attribute `aligned` (see Section 6.4.1.1 [Common Function Attributes], page 622).

6.12.10 Extensions to `enum` Type Declarations

The C23 and C++11 standards added new syntax to specify the underlying type of an `enum` type. For example,

```
enum pet : unsigned char { CAT, DOG, ROCK };
```

In GCC, this feature is supported as an extension in all older dialects of C and C++ as well. For C++ dialects before C++11, use `-Wno-c++11-extensions` to silence the associated warnings.

You can also forward-declare an `enum` type, without specifying its possible values. The enumerators are supplied in a later redeclaration of the type, which must match the underlying type of the first declaration.

```
enum pet : unsigned char;
static enum pet my_pet;
...
enum pet : unsigned char { CAT, DOG, ROCK };
```

Forward declaration of `enum` types with an explicit underlying type is also a feature of C++11 that is supported as an extension by GCC for all C dialects. However, it's not available in C++ dialects prior to C++11.

The C++ standard refers to a forward declaration of an `enum` with an explicit underlying type as an *opaque type*. It is not considered an incomplete type, since its size is known. That means you can declare variables or allocate storage using the type before the redeclaration, not just use pointers of that type.

GCC has also traditionally supported forward declarations of `enum` types that don't include an explicit underlying type specification. This results in an incomplete type, much like what you get if you write `struct foo` without describing the elements. You cannot allocate variables or storage using the type while it is incomplete. However, you can work with pointers to that type.

Forward-declaring an incomplete enum type without an explicit underlying type is supported as an extension in all GNU C dialects, but is not supported at all in GNU C++.

6.12.11 Support for the `_Bool` Type

The C99 standard added `_Bool` as a C language keyword naming the boolean type. As an extension, GNU C also recognizes `_Bool` in C90 mode as well as with `-std=c99` and later.

C23 added `bool` as the preferred name of the boolean type, but `_Bool` also remains a standard keyword in the language and is supported as such by GCC with `-std=c23`.

GNU C++ does not support `_Bool` as a keyword, but including `<stdbool.h>` defines it as a macro in terms of standard C++'s `bool` type.

6.12.12 Macros with a Variable Number of Arguments.

In the ISO C standard of 1999, a macro can be declared to accept a variable number of arguments much as a function can. The syntax for defining the macro is similar to that of a function. Here is an example:

```
#define debug(format, ...) fprintf (stderr, format, __VA_ARGS__)
```

Here '`...`' is a *variable argument*. In the invocation of such a macro, it represents the zero or more tokens until the closing parenthesis that ends the invocation, including any commas. This set of tokens replaces the identifier `__VA_ARGS__` in the macro body wherever it appears. See the CPP manual for more information.

GCC has long supported variadic macros, and used a different syntax that allowed you to give a name to the variable arguments just like any other argument. Here is an example:

```
#define debug(format, args...) fprintf (stderr, format, args)
```

This is in all ways equivalent to the ISO C example above, but arguably more readable and descriptive.

GNU CPP has two further variadic macro extensions, and permits them to be used with either of the above forms of macro definition.

In standard C, you are not allowed to leave the variable argument out entirely; but you are allowed to pass an empty argument. For example, this invocation is invalid in ISO C, because there is no comma after the string:

```
debug ("A message")
```

GNU CPP permits you to completely omit the variable arguments in this way. In the above examples, the compiler would complain, though since the expansion of the macro still has the extra comma after the format string.

To help solve this problem, CPP behaves specially for variable arguments used with the token paste operator, '`##`'. If instead you write

```
#define debug(format, ...) fprintf (stderr, format, ## __VA_ARGS__)
```

and if the variable arguments are omitted or empty, the '`##`' operator causes the preprocessor to remove the comma before it. If you do provide some variable arguments in your macro invocation, GNU CPP does not complain about the paste operation and instead places the variable arguments after the comma. Just like any other pasted macro argument, these arguments are not macro expanded.

6.12.13 Conditionals with Omitted Operands

The middle operand in a conditional expression may be omitted. Then if the first operand is nonzero, its value is the value of the conditional expression.

Therefore, the expression

```
x ? : y
```

has the value of `x` if that is nonzero; otherwise, the value of `y`.

This example is perfectly equivalent to

```
x ? x : y
```

In this simple case, the ability to omit the middle operand is not especially useful. When it becomes useful is when the first operand does, or may (if it is a macro argument), contain a side effect. Then repeating the operand in the middle would perform the side effect twice. Omitting the middle operand uses the value already computed without the undesirable effects of recomputing it.

6.12.14 Case Ranges

You can specify a range of consecutive values in a single `case` label, like this:

```
case low ... high:
```

This has the same effect as the proper number of individual `case` labels, one for each integer value from *low* to *high*, inclusive.

This feature is especially useful for ranges of ASCII character codes:

```
case 'A' ... 'Z':
```

Be careful: Write spaces around the `...`, for otherwise it may be parsed wrong when you use it with integer values. For example, write this:

```
case 1 ... 5:
```

rather than this:

```
case 1...5:
```

6.12.15 Mixed Declarations, Labels and Code

ISO C99 and ISO C++ allow declarations and code to be freely mixed within compound statements. ISO C23 allows labels to be placed before declarations and at the end of a compound statement. As an extension, GNU C also allows all this in C90 mode. For example, you could do:

```
int i;
/* ... */
i++;
int j = i + 2;
```

Each identifier is visible from where it is declared until the end of the enclosing block.

6.12.16 C++ Style Comments

In GNU C, you may use C++ style comments, which start with '`//`' and continue until the end of the line. Many other C implementations allow such comments, and they are included in the 1999 C standard. However, C++ style comments are not recognized if you specify an `-std` option specifying a version of ISO C before C99, or `-ansi` (equivalent to `-std=c90`).

6.12.17 Slightly Looser Rules for Escaped Newlines

The preprocessor treatment of escaped newlines is more relaxed than that specified by the C90 standard, which requires the newline to immediately follow a backslash. GCC's implementation allows whitespace in the form of spaces, horizontal and vertical tabs, and form feeds between the backslash and the subsequent newline. The preprocessor issues a warning, but treats it as a valid escaped newline and combines the two lines to form a single logical line. This works within comments and tokens, as well as between tokens. Comments are *not* treated as whitespace for the purposes of this relaxation, since they have not yet been replaced with spaces.

6.12.18 Hex Floats

ISO C99 and ISO C++17 support floating-point numbers written not only in the usual decimal notation, such as `1.55e1`, but also numbers such as `0x1.fp3` written in hexadecimal format. As a GNU extension, GCC supports this in C90 mode (except in some cases when strictly conforming) and in C++98, C++11 and C++14 modes. In that format the '`0x`' hex introducer and the '`p`' or '`P`' exponent field are mandatory. The exponent is a decimal number that indicates the power of 2 by which the significant part is multiplied. Thus '`0x1.f`' is $1\frac{15}{16}$, '`p3`' multiplies it by 8, and the value of `0x1.fp3` is the same as `1.55e1`.

Unlike for floating-point numbers in the decimal notation the exponent is always required in the hexadecimal notation. Otherwise the compiler would not be able to resolve the ambiguity of, e.g., `0x1.f`. This could mean `1.0f` or `1.9375` since '`f`' is also the extension for floating-point constants of type `float`.

6.12.19 Binary Constants using the '`0b`' Prefix

Integer constants can be written as binary constants, consisting of a sequence of '`0`' and '`1`' digits, prefixed by '`0b`' or '`0B`'. This is particularly useful in environments that operate a lot on the bit level (like microcontrollers).

The following statements are identical:

```
i =       42;
```

```
i =     0x2a;
i =      052;
i = 0b101010;
```

The type of these constants follows the same rules as for octal or hexadecimal integer constants, so suffixes like 'L' or 'UL' can be applied.

6.12.20 Dollar Signs in Identifier Names

In GNU C, you may normally use dollar signs in identifier names. This is because many traditional C implementations allow such identifiers. However, dollar signs in identifiers are not supported on a few target machines, typically because the target assembler does not allow them.

6.12.21 The Character ESC in Constants

You can use the sequence '\e' in a string or character constant to stand for the ASCII character ESC.

6.12.22 Raw String Literals

The C++11 standard added syntax for raw string literals prefixed with 'R'. This syntax allows you to use an arbitrary delimiter sequence instead of escaping special characters within the string. For example, these string constants are all equivalent:

```
const char *s1 = "\\";
const char *s2 = R"(\)";
const char *s3 = R"foo(\)foo";
```

As an extension, GCC also accepts raw string literals in C with `-std=gnu99` or later.

6.12.23 Alternate Keywords

`-ansi` and the various `-std` options disable certain keywords that are GNU C extensions. Specifically, the keywords `asm`, `typeof` and `inline` are not available in programs compiled with `-ansi` or a `-std=` option specifying an ISO standard that doesn't define the keyword. This causes trouble when you want to use these extensions in a header file that can be included in programs that may be compiled with with such options.

The way to solve these problems is to put '__' at the beginning and end of each problematical keyword. For example, use `__asm__` instead of `asm`, and `__inline__` instead of `inline`.

Other C compilers won't accept these alternative keywords; if you want to compile with another compiler, you can define the alternate keywords as macros to replace them with the customary keywords. It looks like this:

```
#ifndef __GNUC__
#define __asm__ asm
#endif
```

`-pedantic` and other options cause warnings for many GNU C extensions. You can suppress such warnings using the keyword `__extension__`. Specifically:

- Writing `__extension__` before an expression prevents warnings about extensions within that expression.
- In C, writing:

  ```
  [[__extension__ ...]]
  ```

suppresses warnings about using '[[]]' attributes in C versions that predate C23.

`__extension__` has no effect aside from this.

6.12.24 Function Names as Strings

GCC provides three magic constants that hold the name of the current function as a string. In C++11 and later modes, all three are treated as constant expressions and can be used in `constexpr` constexts. The first of these constants is `__func__`, which is part of the C99 standard:

The identifier `__func__` is implicitly declared by the translator as if, immediately following the opening brace of each function definition, the declaration

```
static const char __func__[] = "function-name";
```

appeared, where function-name is the name of the lexically-enclosing function. This name is the unadorned name of the function. As an extension, at file (or, in C++, namespace scope), `__func__` evaluates to the empty string.

`__FUNCTION__` is another name for `__func__`, provided for backward compatibility with old versions of GCC.

In C, `__PRETTY_FUNCTION__` is yet another name for `__func__`, except that at file scope (or, in C++, namespace scope), it evaluates to the string `"top level"`. In addition, in C++, `__PRETTY_FUNCTION__` contains the signature of the function as well as its bare name. For example, this program:

```
extern "C" int printf (const char *, ...);

class a {
 public:
  void sub (int i)
    {
      printf ("__FUNCTION__ = %s\n", __FUNCTION__);
      printf ("__PRETTY_FUNCTION__ = %s\n", __PRETTY_FUNCTION__);
    }
};

int
main (void)
{
  a ax;
  ax.sub (0);
  return 0;
}
```

gives this output:

```
__FUNCTION__ = sub
__PRETTY_FUNCTION__ = void a::sub(int)
```

These identifiers are variables, not preprocessor macros, and may not be used to initialize `char` arrays or be concatenated with string literals.

6.13 Extensions to C Semantics

GNU C defines useful behavior for some constructs that are not allowed or well-defined in standard C.

6.13.1 Prototypes and Old-Style Function Definitions

GNU C extends ISO C to allow a function prototype to override a later old-style non-prototype definition. Consider the following example:

```
/* Use prototypes unless the compiler is old-fashioned.  */
#ifdef __STDC__
#define P(x) x
#else
#define P(x) ()
#endif

/* Prototype function declaration.  */
int isroot P((uid_t));

/* Old-style function definition.  */
int
isroot (x)   /* ??? lossage here ??? */
     uid_t x;
{
  return x == 0;
}
```

Suppose the type `uid_t` happens to be `short`. ISO C does not allow this example, because subword arguments in old-style non-prototype definitions are promoted. Therefore in this example the function definition's argument is really an `int`, which does not match the prototype argument type of `short`.

This restriction of ISO C makes it hard to write code that is portable to traditional C compilers, because the programmer does not know whether the `uid_t` type is `short`, `int`, or `long`. Therefore, in cases like these GNU C allows a prototype to override a later old-style definition. More precisely, in GNU C, a function prototype argument type overrides the argument type specified by a later old-style definition if the former type is the same as the latter type before promotion. Thus in GNU C the above example is equivalent to the following:

```
int isroot (uid_t);

int
isroot (uid_t x)
{
  return x == 0;
}
```

GNU C++ does not support old-style function definitions, so this extension is irrelevant.

6.13.2 Arithmetic on `void`- and Function-Pointers

In GNU C, addition and subtraction operations are supported on pointers to `void` and on pointers to functions. This is done by treating the size of a `void` or of a function as 1.

A consequence of this is that `sizeof` is also allowed on `void` and on function types, and returns 1.

The option `-Wpointer-arith` requests a warning if these extensions are used.

6.13.3 Pointer Arguments in Variadic Functions

Standard C requires that pointer types used with `va_arg` in functions with variable argument lists either must be compatible with that of the actual argument, or that one type must be a pointer to `void` and the other a pointer to a character type. GNU C implements the POSIX XSI extension that additionally permits the use of `va_arg` with a pointer type to receive arguments of any other pointer type.

In particular, in GNU C '`va_arg (ap, void *)`' can safely be used to consume an argument of any pointer type.

6.13.4 Pointers to Arrays with Qualifiers Work as Expected

In GNU C, pointers to arrays with qualifiers work similar to pointers to other qualified types. For example, a value of type `int (*)[5]` can be used to initialize a variable of type `const int (*)[5]`. These types are incompatible in ISO C because the `const` qualifier is formally attached to the element type of the array and not the array itself.

```
extern void
transpose (int N, int M, double out[M][N], const double in[N][M]);
double x[3][2];
double y[2][3];
...
transpose(3, 2, y, x);
```

6.13.5 Const and Volatile Functions

The C standard explicitly leaves the behavior of the `const` and `volatile` type qualifiers applied to functions undefined; these constructs can only arise through the use of `typedef`. As an extension, GCC defines this use of the `const` qualifier to have the same meaning as the GCC `const` function attribute, and the `volatile` qualifier to be equivalent to the `noreturn` attribute. See Section 6.4.1.1 [Common Function Attributes], page 622, for more information.

As examples of this usage,

```
/* Equivalent to:
   void fatal () __attribute__ ((noreturn));  */
typedef void voidfn ();
volatile voidfn fatal;

/* Equivalent to:
   extern int square (int) __attribute__ ((const));  */
typedef int intfn (int);
extern const intfn square;
```

In general, using function attributes instead is preferred, since the attributes make both the intent of the code and its reliance on a GNU extension explicit. Additionally, using `const` and `volatile` in this way is specific to GNU C and does not work in GNU C++.

7 Built-in Functions Provided by GCC

GCC provides a very large number of implicitly-declared built-in functions that are typically inlined by the compiler. Some of these builtins directly correspond to standard library routines. Some are for internal use in the processing of exceptions or variable-length argument lists and are not documented here because they may change from time to time; we do not recommend general use of these functions.

The remaining functions are provided either for optimization purposes, or to expose low-level functionality needed to implement features provided by library functions or similar "glue" between GCC and other programming languages or libraries. Others are target-specific, providing direct access to instructions that have no direct C equivalents without the need to write assembly language. There are also builtins to support various kinds of runtime error checking.

Most builtins have names prefixed with '`__builtin_`', although not all of them use this convention. Except as otherwise documented, all built-in functions are available from any of the C family languages supported by GCC.

With the exception of built-ins that have library equivalents such as the standard C library functions discussed below in Section 7.1 [Library Builtins], page 829, or that expand to library calls, GCC built-in functions are always expanded inline and thus do not have corresponding entry points and their address cannot be obtained. Attempting to use them in an expression other than a function call results in a compile-time error.

7.1 Builtins for C Library Functions

GCC includes built-in versions of many of the functions in the standard C library. These functions come in two forms: one whose names start with the `__builtin_` prefix, and the other without. Both forms have the same type (including prototype), the same address (when their address is taken), and the same meaning as the C library functions even if you specify the `-fno-builtin` option see Section 3.4 [C Dialect Options], page 45). Many of these functions are only optimized in certain cases; if they are not optimized in a particular case, a call to the library function is emitted.

Outside strict ISO C mode (`-ansi`, `-std=c90`, `-std=c99` or `-std=c11`), the functions `_exit`, `alloca`, `acospi`, `acospif`, `acospil`, `asinpi`, `asinpif`, `asinpil`, `atan2pi`, `atan2pif`, `atan2pil`, `atanpi`, `atanpif`, `atanpil`, `bcmp`, `bzero`, `cospi`, `cospif`, `cospil`, `dcgettext`, `dgettext`, `dremf`, `dreml`, `drem`, `exp10f`, `exp10l`, `exp10`, `ffsll`, `ffsl`, `ffs`, `fprintf_unlocked`, `fputs_unlocked`, `gammaf`, `gammal`, `gamma`, `gammaf_r`, `gammal_r`, `gamma_r`, `gettext`, `index`, `isascii`, `j0f`, `j0l`, `j0`, `j1f`, `j1l`, `j1`, `jnf`, `jnl`, `jn`, `lgammaf_r`, `lgammal_r`, `lgamma_r`, `mempcpy`, `pow10f`, `pow10l`, `pow10`, `printf_unlocked`, `rindex`, `roundeven`, `roundevenf`, `roundevenl`, `scalbf`, `scalbl`, `scalb`, `signbit`, `signbitf`, `signbitl`, `signbitd32`, `signbitd64`, `signbitd128`, `significandf`, `significandl`, `significand`, `sincosf`, `sincosl`, `sincos`, `sinpif`, `sinpil`, `sinpi`, `stpcpy`, `stpncpy`, `strcasecmp`, `strdup`, `strfmon`, `strncasecmp`, `strndup`, `strnlen`, `tanpif`, `tanpil`, `tanpi`, `toascii`, `y0f`, `y0l`, `y0`, `y1f`, `y1l`, `y1`, `ynf`, `ynl` and `yn` may be handled as built-in functions. All these functions have corresponding versions prefixed with `__builtin_`, which may be used even in strict C90 mode.

The ISO C99 functions `_Exit`, `acoshf`, `acoshl`, `acosh`, `asinhf`, `asinhl`, `asinh`, `atanhf`, `atanhl`, `atanh`, `cabsf`, `cabsl`, `cabs`, `cacosf`, `cacoshf`, `cacoshl`, `cacosh`, `cacosl`, `cacos`, `cargf`, `cargl`, `carg`, `casinf`, `casinhf`, `casinhl`, `casinh`, `casinl`, `casin`, `catanf`, `catanhf`, `catanhl`, `catanh`, `catanl`, `catan`, `cbrtf`, `cbrtl`, `cbrt`, `ccosf`, `ccoshf`, `ccoshl`, `ccosh`, `ccosl`, `ccos`, `cexpf`, `cexpl`, `cexp`, `cimagf`, `cimagl`, `cimag`, `clogf`, `clogl`, `clog`, `conjf`, `conjl`, `conj`, `copysignf`, `copysignl`, `copysign`, `cpowf`, `cpowl`, `cpow`, `cprojf`, `cprojl`, `cproj`, `crealf`, `creall`, `creal`, `csinf`, `csinhf`, `csinhl`, `csinh`, `csinl`, `csin`, `csqrtf`, `csqrtl`, `csqrt`, `ctanf`, `ctanhf`, `ctanhl`, `ctanh`, `ctanl`, `ctan`, `erfcf`, `erfcl`, `erfc`, `erff`, `erfl`, `erf`, `exp2f`, `exp2l`, `exp2`, `expm1f`, `expm1l`, `expm1`, `fdimf`, `fdiml`, `fdim`, `fmaf`, `fmal`, `fmaxf`, `fmaxl`, `fmax`, `fma`, `fminf`, `fminl`, `fmin`, `hypotf`, `hypotl`, `hypot`, `ilogbf`, `ilogbl`, `ilogb`, `imaxabs`, `isblank`, `iswblank`, `lgammaf`, `lgammal`, `lgamma`, `llabs`, `llrintf`, `llrintl`, `llrint`, `llroundf`, `llroundl`, `llround`, `log1pf`, `log1pl`, `log1p`, `log2f`, `log2l`, `log2`, `logbf`, `logbl`, `logb`, `lrintf`, `lrintl`, `lrint`, `lroundf`, `lroundl`, `lround`, `nearbyintf`, `nearbyintl`, `nearbyint`, `nextafterf`, `nextafterl`, `nextafter`, `nexttowardf`, `nexttowardl`, `nexttoward`, `remainderf`, `remainderl`, `remainder`, `remquof`, `remquol`, `remquo`, `rintf`, `rintl`, `rint`, `roundf`, `roundl`, `round`, `scalblnf`, `scalblnl`, `scalbln`, `scalbnf`, `scalbnl`, `scalbn`, `snprintf`, `tgammaf`, `tgammal`, `tgamma`, `truncf`, `truncl`, `trunc`, `vfscanf`, `vscanf`, `vsnprintf` and `vsscanf` are handled as built-in functions except in strict ISO C90 mode (`-ansi` or `-std=c90`).

There are also built-in versions of the ISO C99 functions `acosf`, `acosl`, `asinf`, `asinl`, `atan2f`, `atan2l`, `atanf`, `atanl`, `ceilf`, `ceill`, `cosf`, `coshf`, `coshl`, `cosl`, `expf`, `expl`, `fabsf`, `fabsl`, `floorf`, `floorl`, `fmodf`, `fmodl`, `frexpf`, `frexpl`, `ldexpf`, `ldexpl`, `log10f`, `log10l`, `logf`, `logl`, `modfl`, `modff`, `powf`, `powl`, `sinf`, `sinhf`, `sinhl`, `sinl`, `sqrtf`, `sqrtl`, `tanf`, `tanhf`, `tanhl` and `tanl` that are recognized in any mode since ISO C90 reserves these names for the purpose to which ISO C99 puts them. All these functions have corresponding versions prefixed with `__builtin_`.

There are also built-in functions `__builtin_fabsf`*n*, `__builtin_fabsf`*n*`x`, `__builtin_copysignf`*n* and `__builtin_copysignf`*n*`x`, corresponding to the TS 18661-3 functions `fabsf`*n*, `fabsf`*n*`x`, `copysignf`*n* and `copysignf`*n*`x`, for supported types `_Float`*n* and `_Float`*n*`x`.

There are also GNU extension functions `clog10`, `clog10f` and `clog10l` which names are reserved by ISO C99 for future use. All these functions have versions prefixed with `__builtin_`.

The ISO C94 functions `iswalnum`, `iswalpha`, `iswcntrl`, `iswdigit`, `iswgraph`, `iswlower`, `iswprint`, `iswpunct`, `iswspace`, `iswupper`, `iswxdigit`, `towlower` and `towupper` are handled as built-in functions except in strict ISO C90 mode (`-ansi` or `-std=c90`).

The ISO C90 functions `abort`, `abs`, `acos`, `asin`, `atan2`, `atan`, `calloc`, `ceil`, `cosh`, `cos`, `exit`, `exp`, `fabs`, `floor`, `fmod`, `fprintf`, `fputs`, `free`, `frexp`, `fscanf`, `isalnum`, `isalpha`, `iscntrl`, `isdigit`, `isgraph`, `islower`, `isprint`, `ispunct`, `isspace`, `isupper`, `isxdigit`, `tolower`, `toupper`, `labs`, `ldexp`, `log10`, `log`, `malloc`, `memchr`, `memcmp`, `memcpy`, `memset`, `modf`, `pow`, `printf`, `putchar`, `puts`, `realloc`, `scanf`, `sinh`, `sin`, `snprintf`, `sprintf`, `sqrt`, `sscanf`, `strcat`, `strchr`, `strcmp`, `strcpy`, `strcspn`, `strlen`, `strncat`, `strncmp`, `strncpy`, `strpbrk`, `strrchr`, `strspn`, `strstr`, `tanh`, `tan`, `vfprintf`, `vprintf` and `vsprintf` are all recognized as built-in functions unless `-fno-builtin` is specified (or `-fno-builtin-`*`function`* is specified for an individual function). All of these functions have corresponding versions prefixed with `__builtin_`.

GCC provides built-in versions of the ISO C99 floating-point comparison macros that avoid raising exceptions for unordered operands. They have the same names as the standard macros (`isgreater`, `isgreaterequal`, `isless`, `islessequal`, `islessgreater`, and `isunordered`) , with `__builtin_` prefixed. We intend for a library implementor to be able to simply `#define` each standard macro to its built-in equivalent. In the same fashion, GCC provides `fpclassify`, `iseqsig`, `isfinite`, `isinf_sign`, `isnormal` and `signbit` built-ins used with `__builtin_` prefixed. The `isinf` and `isnan` built-in functions appear both with and without the `__builtin_` prefix. With `-ffinite-math-only` option the `isinf` and `isnan` built-in functions will always return 0.

GCC provides built-in versions of the ISO C99 floating-point rounding and exceptions handling functions `fegetround`, `feclearexcept` and `feraiseexcept`. They may not be available for all targets, and because they need close interaction with libc internal values, they may not be available for all target libcs, but in all cases they will gracefully fallback to libc calls. These built-in functions appear both with and without the `__builtin_` prefix.

7.2 Additional Builtins for Numeric Operations

GCC provides a large set of built-in functions for operating on GCC's extended set of floating-point and integer types (see Section 6.1 [Additional Numeric Types], page 603). The floating-point builtins include functions for building and testing infinities and NaNs. On integer types, there are additional bit manipulation functions, byte-swapping, and CRC functions.

Many of these builtins are type-generic and can operate on any floating-point or integer operand.

7.2.1 Floating-Point Format Builtins

`double __builtin_huge_val (void)` [Built-in Function]

Returns a positive infinity, if supported by the floating-point format, else `DBL_MAX`. This function is suitable for implementing the ISO C macro `HUGE_VAL`.

`float __builtin_huge_valf (void)` [Built-in Function]

Similar to `__builtin_huge_val`, except the return type is `float`.

`long double __builtin_huge_vall (void)` [Built-in Function]

Similar to `__builtin_huge_val`, except the return type is `long double`.

`_Float`*n* `__builtin_huge_valf`*n* `(void)` [Built-in Function]

Similar to `__builtin_huge_val`, except the return type is `_Float`*n*.

`_Float`*n*`x __builtin_huge_valf`*n*`x (void)` [Built-in Function]

Similar to `__builtin_huge_val`, except the return type is `_Float`*n*`x`.

`int __builtin_fpclassify (int, int, int, int, int, ...)` [Built-in Function]

This built-in implements the C99 fpclassify functionality. The first five int arguments should be the target library's notion of the possible FP classes and are used for return values. They must be constant values and they must appear in this order: `FP_NAN`, `FP_INFINITE`, `FP_NORMAL`, `FP_SUBNORMAL` and `FP_ZERO`. The ellipsis is for exactly one floating-point value to classify. GCC treats the last argument as type-generic, which means it does not do default promotion from float to double.

`double __builtin_inf (void)` [Built-in Function]
Similar to `__builtin_huge_val`, except a warning is generated if the target floating-point format does not support infinities.

`_Decimal32 __builtin_infd32 (void)` [Built-in Function]
Similar to `__builtin_inf`, except the return type is `_Decimal32`.

`_Decimal64 __builtin_infd64 (void)` [Built-in Function]
Similar to `__builtin_inf`, except the return type is `_Decimal64`.

`_Decimal128 __builtin_infd128 (void)` [Built-in Function]
Similar to `__builtin_inf`, except the return type is `_Decimal128`.

`float __builtin_inff (void)` [Built-in Function]
Similar to `__builtin_inf`, except the return type is `float`. This function is suitable for implementing the ISO C99 macro `INFINITY`.

`long double __builtin_infl (void)` [Built-in Function]
Similar to `__builtin_inf`, except the return type is `long double`.

`_Floatn __builtin_inffn (void)` [Built-in Function]
Similar to `__builtin_inf`, except the return type is `_Floatn`.

`_Floatn __builtin_inffnx (void)` [Built-in Function]
Similar to `__builtin_inf`, except the return type is `_Floatnx`.

`int __builtin_isinf_sign (...)` [Built-in Function]
Similar to `isinf`, except the return value is -1 for an argument of `-Inf` and 1 for an argument of `+Inf`. Note while the parameter list is an ellipsis, this function only accepts exactly one floating-point argument. GCC treats this parameter as type-generic, which means it does not do default promotion from float to double.

`double __builtin_nan (const char *str)` [Built-in Function]
This is an implementation of the ISO C99 function `nan`.

Since ISO C99 defines this function in terms of `strtod`, which we do not implement, a description of the parsing is in order. The string is parsed as by `strtol`; that is, the base is recognized by leading '`0`' or '`0x`' prefixes. The number parsed is placed in the significand such that the least significant bit of the number is at the least significant bit of the significand. The number is truncated to fit the significand field provided. The significand is forced to be a quiet NaN.

This function, if given a string literal all of which would have been consumed by `strtol`, is evaluated early enough that it is considered a compile-time constant.

`_Decimal32 __builtin_nand32 (const char *str)` [Built-in Function]
Similar to `__builtin_nan`, except the return type is `_Decimal32`.

`_Decimal64 __builtin_nand64 (const char *str)` [Built-in Function]
Similar to `__builtin_nan`, except the return type is `_Decimal64`.

`_Decimal128 __builtin_nand128 (const char *str)` [Built-in Function]
Similar to `__builtin_nan`, except the return type is `_Decimal128`.

`float __builtin_nanf (const char *str)` [Built-in Function]
Similar to `__builtin_nan`, except the return type is `float`.

`long double __builtin_nanl (const char *str)` [Built-in Function]
Similar to `__builtin_nan`, except the return type is `long double`.

`_Floatn __builtin_nanfn (const char *str)` [Built-in Function]
Similar to `__builtin_nan`, except the return type is `_Floatn`.

`_Floatnx __builtin_nanfnx (const char *str)` [Built-in Function]
Similar to `__builtin_nan`, except the return type is `_Floatnx`.

`double __builtin_nans (const char *str)` [Built-in Function]
Similar to `__builtin_nan`, except the significand is forced to be a signaling NaN. The `nans` function is proposed by WG14 N965.

`_Decimal32 __builtin_nansd32 (const char *str)` [Built-in Function]
Similar to `__builtin_nans`, except the return type is `_Decimal32`.

`_Decimal64 __builtin_nansd64 (const char *str)` [Built-in Function]
Similar to `__builtin_nans`, except the return type is `_Decimal64`.

`_Decimal128 __builtin_nansd128 (const char *str)` [Built-in Function]
Similar to `__builtin_nans`, except the return type is `_Decimal128`.

`float __builtin_nansf (const char *str)` [Built-in Function]
Similar to `__builtin_nans`, except the return type is `float`.

`long double __builtin_nansl (const char *str)` [Built-in Function]
Similar to `__builtin_nans`, except the return type is `long double`.

`_Floatn __builtin_nansfn (const char *str)` [Built-in Function]
Similar to `__builtin_nans`, except the return type is `_Floatn`.

`_Floatnx __builtin_nansfnx (const char *str)` [Built-in Function]
Similar to `__builtin_nans`, except the return type is `_Floatnx`.

`int __builtin_issignaling (...)` [Built-in Function]
Return non-zero if the argument is a signaling NaN and zero otherwise. Note while the parameter list is an ellipsis, this function only accepts exactly one floating-point argument. GCC treats this parameter as type-generic, which means it does not do default promotion from float to double. This built-in function can work even without the non-default `-fsignaling-nans` option, although if a signaling NaN is computed, stored or passed as argument to some function other than this built-in in the current translation unit, it is safer to use `-fsignaling-nans`. With `-ffinite-math-only` option this built-in function will always return 0.

`double __builtin_powi (double, int)` [Built-in Function]
`float __builtin_powif (float, int)` [Built-in Function]
`long double __builtin_powil (long double, int)` [Built-in Function]

Returns the first argument raised to the power of the second. Unlike the `pow` function no guarantees about precision and rounding are made.

7.2.2 Bit Operation Builtins

`int __builtin_ffs (int x)` [Built-in Function]

Returns one plus the index of the least significant 1-bit of *x*, or if *x* is zero, returns zero.

`int __builtin_clz (unsigned int x)` [Built-in Function]

Returns the number of leading 0-bits in *x*, starting at the most significant bit position. If *x* is 0, the result is undefined.

`int __builtin_ctz (unsigned int x)` [Built-in Function]

Returns the number of trailing 0-bits in *x*, starting at the least significant bit position. If *x* is 0, the result is undefined.

`int __builtin_clrsb (int x)` [Built-in Function]

Returns the number of leading redundant sign bits in *x*, i.e. the number of bits following the most significant bit that are identical to it. There are no special cases for 0 or other values.

`int __builtin_popcount (unsigned int x)` [Built-in Function]

Returns the number of 1-bits in *x*.

`int __builtin_parity (unsigned int x)` [Built-in Function]

Returns the parity of *x*, i.e. the number of 1-bits in *x* modulo 2.

`int __builtin_ffsl (long)` [Built-in Function]

Similar to `__builtin_ffs`, except the argument type is `long`.

`int __builtin_clzl (unsigned long)` [Built-in Function]

Similar to `__builtin_clz`, except the argument type is `unsigned long`.

`int __builtin_ctzl (unsigned long)` [Built-in Function]

Similar to `__builtin_ctz`, except the argument type is `unsigned long`.

`int __builtin_clrsbl (long)` [Built-in Function]

Similar to `__builtin_clrsb`, except the argument type is `long`.

`int __builtin_popcountl (unsigned long)` [Built-in Function]

Similar to `__builtin_popcount`, except the argument type is `unsigned long`.

`int __builtin_parityl (unsigned long)` [Built-in Function]

Similar to `__builtin_parity`, except the argument type is `unsigned long`.

`int __builtin_ffsll (long long)` [Built-in Function]

Similar to `__builtin_ffs`, except the argument type is `long long`.

`int __builtin_clzll (unsigned long long)` [Built-in Function]
Similar to `__builtin_clz`, except the argument type is `unsigned long long`.

`int __builtin_ctzll (unsigned long long)` [Built-in Function]
Similar to `__builtin_ctz`, except the argument type is `unsigned long long`.

`int __builtin_clrsbll (long long)` [Built-in Function]
Similar to `__builtin_clrsb`, except the argument type is `long long`.

`int __builtin_popcountll (unsigned long long)` [Built-in Function]
Similar to `__builtin_popcount`, except the argument type is `unsigned long long`.

`int __builtin_parityll (unsigned long long)` [Built-in Function]
Similar to `__builtin_parity`, except the argument type is `unsigned long long`.

`int __builtin_ffsg (...)` [Built-in Function]
Similar to `__builtin_ffs`, except the argument is type-generic signed integer (standard, extended or bit-precise). No integral argument promotions are performed on the argument.

`int __builtin_clzg (...)` [Built-in Function]
Similar to `__builtin_clz`, except the argument is type-generic unsigned integer (standard, extended or bit-precise) and there is optional second argument with int type. No integral argument promotions are performed on the first argument. If two arguments are specified, and first argument is 0, the result is the second argument. If only one argument is specified and it is 0, the result is undefined.

`int __builtin_ctzg (...)` [Built-in Function]
Similar to `__builtin_ctz`, except the argument is type-generic unsigned integer (standard, extended or bit-precise) and there is optional second argument with int type. No integral argument promotions are performed on the first argument. If two arguments are specified, and first argument is 0, the result is the second argument. If only one argument is specified and it is 0, the result is undefined.

`int __builtin_clrsbg (...)` [Built-in Function]
Similar to `__builtin_clrsb`, except the argument is type-generic signed integer (standard, extended or bit-precise). No integral argument promotions are performed on the argument.

`int __builtin_popcountg (...)` [Built-in Function]
Similar to `__builtin_popcount`, except the argument is type-generic unsigned integer (standard, extended or bit-precise). No integral argument promotions are performed on the argument.

`int __builtin_parityg (...)` [Built-in Function]
Similar to `__builtin_parity`, except the argument is type-generic unsigned integer (standard, extended or bit-precise). No integral argument promotions are performed on the argument.

type `__builtin_stdc_bit_ceil` (*type arg*) [Built-in Function]

The `__builtin_stdc_bit_ceil` function is available only in C. It is type-generic, the argument can be any unsigned integer (standard, extended or bit-precise). No integral argument promotions are performed on the argument. It is equivalent to `arg <= 1 ? (type) 1 : (type) 2 << (prec - 1 - __builtin_clzg ((type) (arg - 1)))` where *prec* is bit width of *type*, except that side-effects in *arg* are evaluated just once.

type `__builtin_stdc_bit_floor` (*type arg*) [Built-in Function]

The `__builtin_stdc_bit_floor` function is available only in C. It is type-generic, the argument can be any unsigned integer (standard, extended or bit-precise). No integral argument promotions are performed on the argument. It is equivalent to `arg == 0 ? (type) 0 : (type) 1 << (prec - 1 - __builtin_clzg (arg))` where *prec* is bit width of *type*, except that side-effects in *arg* are evaluated just once.

`unsigned int __builtin_stdc_bit_width` (*type arg*) [Built-in Function]

The `__builtin_stdc_bit_width` function is available only in C. It is type-generic, the argument can be any unsigned integer (standard, extended or bit-precise). No integral argument promotions are performed on the argument. It is equivalent to `(unsigned int) (prec - __builtin_clzg (arg, prec))` where *prec* is bit width of *type*.

`unsigned int __builtin_stdc_count_ones` (*type arg*) [Built-in Function]

The `__builtin_stdc_count_ones` function is available only in C. It is type-generic, the argument can be any unsigned integer (standard, extended or bit-precise). No integral argument promotions are performed on the argument. It is equivalent to `(unsigned int) __builtin_popcountg (arg)`

`unsigned int __builtin_stdc_count_zeros` (*type arg*) [Built-in Function]

The `__builtin_stdc_count_zeros` function is available only in C. It is type-generic, the argument can be any unsigned integer (standard, extended or bit-precise). No integral argument promotions are performed on the argument. It is equivalent to `(unsigned int) __builtin_popcountg ((type) ~arg)`

`unsigned int __builtin_stdc_first_leading_one` (*type arg*) [Built-in Function]

The `__builtin_stdc_first_leading_one` function is available only in C. It is type-generic, the argument can be any unsigned integer (standard, extended or bit-precise). No integral argument promotions are performed on the argument. It is equivalent to `__builtin_clzg (arg, -1) + 1U`

`unsigned int __builtin_stdc_first_leading_zero` (*type arg*) [Built-in Function]

The `__builtin_stdc_first_leading_zero` function is available only in C. It is type-generic, the argument can be any unsigned integer (standard, extended or bit-precise). No integral argument promotions are performed on the argument. It is equivalent to `__builtin_clzg ((type) ~arg, -1) + 1U` unsigned int __builtin_stdc_first_trailing_one (*type arg*) [Built-in Function]

The __builtin_stdc_first_trailing_one function is available only in C. It is type-generic, the argument can be any unsigned integer (standard, extended or bit-precise). No integral argument promotions are performed on the argument. It is equivalent to __builtin_ctzg (*arg*, -1) + 1U

unsigned int __builtin_stdc_first_trailing_zero (*type arg*) [Built-in Function]

The __builtin_stdc_first_trailing_zero function is available only in C. It is type-generic, the argument can be any unsigned integer (standard, extended or bit-precise). No integral argument promotions are performed on the argument. It is equivalent to __builtin_ctzg ((*type*) ~*arg*, -1) + 1U

unsigned int __builtin_stdc_has_single_bit (*type arg*) [Built-in Function]

The __builtin_stdc_has_single_bit function is available only in C. It is type-generic, the argument can be any unsigned integer (standard, extended or bit-precise). No integral argument promotions are performed on the argument. It is equivalent to (_Bool) (__builtin_popcountg (*arg*) == 1)

unsigned int __builtin_stdc_leading_ones (*type arg*) [Built-in Function]

The __builtin_stdc_leading_ones function is available only in C. It is type-generic, the argument can be any unsigned integer (standard, extended or bit-precise). No integral argument promotions are performed on the argument. It is equivalent to (unsigned int) __builtin_clzg ((*type*) ~*arg*, *prec*)

unsigned int __builtin_stdc_leading_zeros (*type arg*) [Built-in Function]

The __builtin_stdc_leading_zeros function is available only in C. It is type-generic, the argument can be any unsigned integer (standard, extended or bit-precise). No integral argument promotions are performed on the argument. It is equivalent to (unsigned int) __builtin_clzg (*arg*, *prec*)

unsigned int __builtin_stdc_trailing_ones (*type arg*) [Built-in Function]

The __builtin_stdc_trailing_ones function is available only in C. It is type-generic, the argument can be any unsigned integer (standard, extended or bit-precise). No integral argument promotions are performed on the argument. It is equivalent to (unsigned int) __builtin_ctzg ((*type*) ~*arg*, *prec*)

unsigned int __builtin_stdc_trailing_zeros (*type arg*) [Built-in Function]

The __builtin_stdc_trailing_zeros function is available only in C. It is type-generic, the argument can be any unsigned integer (standard, extended or bit-precise). No integral argument promotions are performed on the argument. It is equivalent to (unsigned int) __builtin_ctzg (*arg*, *prec*)

type1 __builtin_stdc_rotate_left (*type1 arg1*, *type2 arg2*) [Built-in Function]

The __builtin_stdc_rotate_left function is available only in C. It is type-generic, the first argument can be any unsigned integer (standard, extended or bit-precise) and second argument any signed or unsigned integer or `char`. No integral argument promotions are performed on the arguments. It is equivalent to `(`*type1*`) ((`*arg1* `<< (`*arg2* `%` *prec*`)) | (`*arg1* `>> ((-(unsigned` *type2*`)` *arg2*`)` `%` *prec*`)))` where *prec* is bit width of *type1*, except that side-effects in *arg1* and *arg2* are evaluated just once. The behavior is undefined if *arg2* is negative.

type1 `__builtin_stdc_rotate_right` (*type1* *arg1*, *type2* *arg2*) [Built-in Function]

The `__builtin_stdc_rotate_right` function is available only in C. It is type-generic, the first argument can be any unsigned integer (standard, extended or bit-precise) and second argument any signed or unsigned integer or `char`. No integral argument promotions are performed on the arguments. It is equivalent to `(`*type1*`) ((`*arg1* `>> (`*arg2* `%` *prec*`)) | (`*arg1* `<< ((-(unsigned` *type2*`)` *arg2*`)` `%` *prec*`)))` where *prec* is bit width of *type1*, except that side-effects in *arg1* and *arg2* are evaluated just once. The behavior is undefined if *arg2* is negative.

7.2.3 Byte-Swapping Builtins

`uint16_t __builtin_bswap16 (uint16_t` *x*`)` [Built-in Function]

Returns *x* with the order of the bytes reversed; for example, `0xabcd` becomes `0xcdab`. Byte here always means exactly 8 bits.

`uint32_t __builtin_bswap32 (uint32_t` *x*`)` [Built-in Function]

Similar to `__builtin_bswap16`, except the argument and return types are 32-bit.

`uint64_t __builtin_bswap64 (uint64_t` *x*`)` [Built-in Function]

Similar to `__builtin_bswap32`, except the argument and return types are 64-bit.

`uint128_t __builtin_bswap128 (uint128_t` *x*`)` [Built-in Function]

Similar to `__builtin_bswap64`, except the argument and return types are 128-bit. Only supported on targets when 128-bit types are supported.

7.2.4 CRC Builtins

`uint8_t __builtin_rev_crc8_data8 (uint8_t` *crc*`, uint8_t` *data*`, uint8_t` *poly*`)` [Built-in Function]

Returns the calculated 8-bit bit-reversed CRC using the initial CRC (8-bit), data (8-bit) and the polynomial (8-bit). *crc* is the initial CRC, *data* is the data and *poly* is the polynomial without leading 1. *poly* is required to be a compile-time constant. Table-based or clmul-based CRC may be used for the calculation, depending on the target architecture.

`uint16_t __builtin_rev_crc16_data16 (uint16_t` *crc*`, uint16_t` *data*`, uint16_t` *poly*`)` [Built-in Function]

Similar to `__builtin_rev_crc8_data8`, except the argument and return types are 16-bit.

`uint16_t __builtin_rev_crc16_data8 (uint16_t` *crc*`, uint8_t` *data*`, uint16_t` *poly*`)` [Built-in Function]

Similar to `__builtin_rev_crc16_data16`, except the *data* argument type is 8-bit.

`uint32_t __builtin_rev_crc32_data32 (uint32_t crc, uint32_t data, uint32_t poly)` [Built-in Function]

Similar to `__builtin_rev_crc8_data8`, except the argument and return types are 32-bit and for the CRC calculation may be also used crc* machine instruction depending on the target and the polynomial.

`uint32_t __builtin_rev_crc32_data8 (uint32_t crc, uint8_t data, uint32_t poly)` [Built-in Function]

Similar to `__builtin_rev_crc32_data32`, except the *data* argument type is 8-bit.

`uint32_t __builtin_rev_crc32_data16 (uint32_t crc, uint16_t data, uint32_t poly)` [Built-in Function]

Similar to `__builtin_rev_crc32_data32`, except the *data* argument type is 16-bit.

`uint64_t __builtin_rev_crc64_data64 (uint64_t crc, uint64_t data, uint64_t poly)` [Built-in Function]

Similar to `__builtin_rev_crc8_data8`, except the argument and return types are 64-bit.

`uint64_t __builtin_rev_crc64_data8 (uint64_t crc, uint8_t data, uint64_t poly)` [Built-in Function]

Similar to `__builtin_rev_crc64_data64`, except the *data* argument type is 8-bit.

`uint64_t __builtin_rev_crc64_data16 (uint64_t crc, uint16_t data, uint64_t poly)` [Built-in Function]

Similar to `__builtin_rev_crc64_data64`, except the *data* argument type is 16-bit.

`uint64_t __builtin_rev_crc64_data32 (uint64_t crc, uint32_t data, uint64_t poly)` [Built-in Function]

Similar to `__builtin_rev_crc64_data64`, except the *data* argument type is 32-bit.

`uint8_t __builtin_crc8_data8 (uint8_t crc, uint8_t data, uint8_t poly)` [Built-in Function]

Returns the calculated 8-bit bit-forward CRC using the initial CRC (8-bit), data (8-bit) and the polynomial (8-bit). *crc* is the initial CRC, *data* is the data and *poly* is the polynomial without leading 1. *poly* is required to be a compile-time constant. Table-based or clmul-based CRC may be used for the calculation, depending on the target architecture.

`uint16_t __builtin_crc16_data16 (uint16_t crc, uint16_t data, uint16_t poly)` [Built-in Function]

Similar to `__builtin_crc8_data8`, except the argument and return types are 16-bit.

`uint16_t __builtin_crc16_data8 (uint16_t crc, uint8_t data, uint16_t poly)` [Built-in Function]

Similar to `__builtin_crc16_data16`, except the *data* argument type is 8-bit.

`uint32_t __builtin_crc32_data32 (uint32_t crc, uint32_t data, uint32_t poly)` [Built-in Function]

Similar to `__builtin_crc8_data8`, except the argument and return types are 32-bit.

`uint32_t __builtin_crc32_data8 (uint32_t crc, uint8_t data, uint32_t poly)` [Built-in Function]

Similar to `__builtin_crc32_data32`, except the *data* argument type is 8-bit.

`uint32_t __builtin_crc32_data16 (uint32_t crc, uint16_t data, uint32_t poly)` [Built-in Function]

Similar to `__builtin_crc32_data32`, except the *data* argument type is 16-bit.

`uint64_t __builtin_crc64_data64 (uint64_t crc, uint64_t data, uint64_t poly)` [Built-in Function]

Similar to `__builtin_crc8_data8`, except the argument and return types are 64-bit.

`uint64_t __builtin_crc64_data8 (uint64_t crc, uint8_t data, uint64_t poly)` [Built-in Function]

Similar to `__builtin_crc64_data64`, except the *data* argument type is 8-bit.

`uint64_t __builtin_crc64_data16 (uint64_t crc, uint16_t data, uint64_t poly)` [Built-in Function]

Similar to `__builtin_crc64_data64`, except the *data* argument type is 16-bit.

`uint64_t __builtin_crc64_data32 (uint64_t crc, uint32_t data, uint64_t poly)` [Built-in Function]

Similar to `__builtin_crc64_data64`, except the *data* argument type is 32-bit.

7.2.5 Built-in Functions to Perform Arithmetic with Overflow Checking

The following built-in functions allow performing simple arithmetic operations together with checking whether the operations overflowed.

`bool __builtin_add_overflow (type1 a, type2 b, type3 *res)` [Built-in Function]

`bool __builtin_sadd_overflow (int a, int b, int *res)` [Built-in Function]

`bool __builtin_saddl_overflow (long int a, long int b, long int *res)` [Built-in Function]

`bool __builtin_saddll_overflow (long long int a, long long int b, long long int *res)` [Built-in Function]

`bool __builtin_uadd_overflow (unsigned int a, unsigned int b, unsigned int *res)` [Built-in Function]

`bool __builtin_uaddl_overflow (unsigned long int a, unsigned long int b, unsigned long int *res)` [Built-in Function]

`bool __builtin_uaddll_overflow (unsigned long long int a, unsigned long long int b, unsigned long long int *res)` [Built-in Function]

These built-in functions promote the first two operands into infinite precision signed type and perform addition on those promoted operands. The result is then cast to the type the third pointer argument points to and stored there. If the stored result is equal to the infinite precision result, the built-in functions return `false`, otherwise they return `true`. As the addition is performed in infinite signed precision, these built-in functions have fully defined behavior for all argument values.

The first built-in function allows arbitrary integral types for operands and the result type must be pointer to some integral type other than enumerated or boolean type, the rest of the built-in functions have explicit integer types.

The compiler will attempt to use hardware instructions to implement these built-in functions where possible, like conditional jump on overflow after addition, conditional jump on carry etc.

`bool __builtin_sub_overflow (`*type1 a*`, `*type2 b*`, `*type3 *res*`)` [Built-in Function]

`bool __builtin_ssub_overflow (int `*a*`, int `*b*`, int *`*res*`)` [Built-in Function]

`bool __builtin_ssubl_overflow (long int `*a*`, long int `*b*`, long int *`*res*`)` [Built-in Function]

`bool __builtin_ssubll_overflow (long long int `*a*`, long long int `*b*`, long long int *`*res*`)` [Built-in Function]

`bool __builtin_usub_overflow (unsigned int `*a*`, unsigned int `*b*`, unsigned int *`*res*`)` [Built-in Function]

`bool __builtin_usubl_overflow (unsigned long int `*a*`, unsigned long int `*b*`, unsigned long int *`*res*`)` [Built-in Function]

`bool __builtin_usubll_overflow (unsigned long long int `*a*`, unsigned long long int `*b*`, unsigned long long int *`*res*`)` [Built-in Function]

These built-in functions are similar to the add overflow checking built-in functions above, except they perform subtraction, subtract the second argument from the first one, instead of addition.

`bool __builtin_mul_overflow (`*type1 a*`, `*type2 b*`, `*type3 *res*`)` [Built-in Function]

`bool __builtin_smul_overflow (int `*a*`, int `*b*`, int *`*res*`)` [Built-in Function]

`bool __builtin_smull_overflow (long int `*a*`, long int `*b*`, long int *`*res*`)` [Built-in Function]

`bool __builtin_smulll_overflow (long long int `*a*`, long long int `*b*`, long long int *`*res*`)` [Built-in Function]

`bool __builtin_umul_overflow (unsigned int `*a*`, unsigned int `*b*`, unsigned int *`*res*`)` [Built-in Function]

`bool __builtin_umull_overflow (unsigned long int `*a*`, unsigned long int `*b*`, unsigned long int *`*res*`)` [Built-in Function]

`bool __builtin_umulll_overflow (unsigned long long int `*a*`, unsigned long long int `*b*`, unsigned long long int *`*res*`)` [Built-in Function]

These built-in functions are similar to the add overflow checking built-in functions above, except they perform multiplication, instead of addition.

The following built-in functions allow checking if simple arithmetic operation would overflow.

bool __builtin_add_overflow_p (*type1 a*, *type2 b*, *type3 c*) [Built-in Function]
bool __builtin_sub_overflow_p (*type1 a*, *type2 b*, *type3 c*) [Built-in Function]
bool __builtin_mul_overflow_p (*type1 a*, *type2 b*, *type3 c*) [Built-in Function]

These built-in functions are similar to `__builtin_add_overflow`, `__builtin_sub_overflow`, or `__builtin_mul_overflow`, except that they don't store the result of the arithmetic operation anywhere and the last argument is not a pointer, but some expression with integral type other than enumerated or boolean type.

The built-in functions promote the first two operands into infinite precision signed type and perform addition on those promoted operands. The result is then cast to the type of the third argument. If the cast result is equal to the infinite precision result, the built-in functions return `false`, otherwise they return `true`. The value of the third argument is ignored, just the side effects in the third argument are evaluated, and no integral argument promotions are performed on the last argument. If the third argument is a bit-field, the type used for the result cast has the precision and signedness of the given bit-field, rather than precision and signedness of the underlying type.

For example, the following macro can be used to portably check, at compile-time, whether or not adding two constant integers will overflow, and perform the addition only when it is known to be safe and not to trigger a `-Woverflow` warning.

```
#define INT_ADD_OVERFLOW_P(a, b) \
   __builtin_add_overflow_p (a, b, (__typeof__ ((a) + (b))) 0)

enum {
    A = INT_MAX, B = 3,
    C = INT_ADD_OVERFLOW_P (A, B) ? 0 : A + B,
    D = __builtin_add_overflow_p (1, SCHAR_MAX, (signed char) 0)
};
```

The compiler will attempt to use hardware instructions to implement these built-in functions where possible, like conditional jump on overflow after addition, conditional jump on carry etc.

unsigned int __builtin_addc (unsigned int *a*, unsigned int *b*, unsigned int *carry_in*, unsigned int **carry_out*) [Built-in Function]
unsigned long int __builtin_addcl (unsigned long int *a*, unsigned long int *b*, unsigned int *carry_in*, unsigned long int **carry_out*) [Built-in Function]
unsigned long long int __builtin_addcll (unsigned long long int *a*, unsigned long long int *b*, unsigned long long int *carry_in*, unsigned long long int **carry_out*) [Built-in Function]

These built-in functions are equivalent to:

```
({ __typeof__ (a) s; \
    __typeof__ (a) c1 = __builtin_add_overflow (a, b, &s); \
    __typeof__ (a) c2 = __builtin_add_overflow (s, carry_in, &s); \
    *(carry_out) = c1 | c2; \
    s; })
```

i.e. they add 3 unsigned values, set what the last argument points to to 1 if any of the two additions overflowed (otherwise 0) and return the sum of those 3 unsigned values. Note, while all the first 3 arguments can have arbitrary values, better code will be emitted if one of them (preferably the third one) has only values 0 or 1 (i.e. carry-in).

`unsigned int __builtin_subc (unsigned int a, unsigned int b, unsigned int carry_in, unsigned int *carry_out)` [Built-in Function]

`unsigned long int __builtin_subcl (unsigned long int a, unsigned long int b, unsigned int carry_in, unsigned long int *carry_out)` [Built-in Function]

`unsigned long long int __builtin_subcll (unsigned long long int a, unsigned long long int b, unsigned long long int carry_in, unsigned long long int *carry_out)` [Built-in Function]

These built-in functions are equivalent to:

```
({ __typeof__ (a) s; \
    __typeof__ (a) c1 = __builtin_sub_overflow (a, b, &s); \
    __typeof__ (a) c2 = __builtin_sub_overflow (s, carry_in, &s); \
    *(carry_out) = c1 | c2; \
    s; })
```

i.e. they subtract 2 unsigned values from the first unsigned value, set what the last argument points to to 1 if any of the two subtractions overflowed (otherwise 0) and return the result of the subtractions. Note, while all the first 3 arguments can have arbitrary values, better code will be emitted if one of them (preferrably the third one) has only values 0 or 1 (i.e. carry-in).

7.3 Builtins for Stack Allocation

`void * __builtin_alloca (size_t size)` [Built-in Function]

The `__builtin_alloca` function must be called at block scope. The function allocates an object *size* bytes large on the stack of the calling function. The object is aligned on the default stack alignment boundary for the target determined by the `__BIGGEST_ALIGNMENT__` macro. The `__builtin_alloca` function returns a pointer to the first byte of the allocated object. The lifetime of the allocated object ends just before the calling function returns to its caller. This is so even when `__builtin_alloca` is called within a nested block.

For example, the following function allocates eight objects of `n` bytes each on the stack, storing a pointer to each in consecutive elements of the array `a`. It then passes the array to function `g` which can safely use the storage pointed to by each of the array elements.

```
void f (unsigned n)
{
  void *a [8];
  for (int i = 0; i != 8; ++i)
    a [i] = __builtin_alloca (n);

  g (a, n);   // safe
}
```

Since the `__builtin_alloca` function doesn't validate its argument it is the responsibility of its caller to make sure the argument doesn't cause it to exceed the stack size limit. The `__builtin_alloca` function is provided to make it possible to allocate on the stack arrays of bytes with an upper bound that may be computed at run time. Since C99 Variable Length Arrays offer similar functionality under a portable, more convenient, and safer interface they are recommended instead, in both C99 and C++ programs where GCC provides them as an extension. See Section 6.2.1 [Variable Length], page 609, for details.

`void * __builtin_alloca_with_align (size_t` *size*`, size_t` *alignment*`)` [Built-in Function]

The `__builtin_alloca_with_align` function must be called at block scope. The function allocates an object *size* bytes large on the stack of the calling function. The allocated object is aligned on the boundary specified by the argument *alignment* whose unit is given in bits (not bytes). The *size* argument must be positive and not exceed the stack size limit. The *alignment* argument must be a constant integer expression that evaluates to a power of 2 greater than or equal to `CHAR_BIT` and less than some unspecified maximum. Invocations with other values are rejected with an error indicating the valid bounds. The function returns a pointer to the first byte of the allocated object. The lifetime of the allocated object ends at the end of the block in which the function was called. The allocated storage is released no later than just before the calling function returns to its caller, but may be released at the end of the block in which the function was called.

For example, in the following function the call to `g` is unsafe because when `overalign` is non-zero, the space allocated by `__builtin_alloca_with_align` may have been released at the end of the `if` statement in which it was called.

```
void f (unsigned n, bool overalign)
{
  void *p;
  if (overalign)
    p = __builtin_alloca_with_align (n, 64 /* bits */);
  else
    p = __builtin_alloc (n);

  g (p, n);   // unsafe
}
```

Since the `__builtin_alloca_with_align` function doesn't validate its *size* argument it is the responsibility of its caller to make sure the argument doesn't cause it to exceed the stack size limit. The `__builtin_alloca_with_align` function is provided to make it possible to allocate on the stack overaligned arrays of bytes with an upper bound that may be computed at run time. Since C99 Variable Length Arrays offer the same functionality under a portable, more convenient, and safer interface they are recommended instead, in both C99 and C++ programs where GCC provides them as an extension. See Section 6.2.1 [Variable Length], page 609, for details.

`void * __builtin_alloca_with_align_and_max (size_t` *size*`, size_t` *alignment*`, size_t` *max_size*`)` [Built-in Function]

Similar to `__builtin_alloca_with_align` but takes an extra argument specifying an upper bound for *size* in case its value cannot be computed at compile time, for use by `-fstack-usage`, `-Wstack-usage` and `-Walloca-larger-than`. *max_size* must be a constant integer expression, it has no effect on code generation and no attempt is made to check its compatibility with *size*.

7.4 Nonlocal Gotos

GCC provides the built-in functions `__builtin_setjmp` and `__builtin_longjmp` which are similar to, but not interchangeable with, the C library functions `setjmp` and `longjmp`. The built-in versions are used internally by GCC's libraries to implement exception handling on some targets. You should use the standard C library functions declared in `<setjmp.h>` in user code instead of the builtins.

The built-in versions of these functions use GCC's normal mechanisms to save and restore registers using the stack on function entry and exit. The jump buffer argument *buf* holds only the information needed to restore the stack frame, rather than the entire set of saved register values.

An important caveat is that GCC arranges to save and restore only those registers known to the specific architecture variant being compiled for. This can make `__builtin_setjmp` and `__builtin_longjmp` more efficient than their library counterparts in some cases, but it can also cause incorrect and mysterious behavior when mixing with code that uses the full register set.

You should declare the jump buffer argument *buf* to the built-in functions as:

```
#include <stdint.h>
intptr_t buf[5];
```

`int __builtin_setjmp (intptr_t *buf)` [Built-in Function]

This function saves the current stack context in *buf*. `__builtin_setjmp` returns 0 when returning directly, and 1 when returning from `__builtin_longjmp` using the same *buf*.

`void __builtin_longjmp (intptr_t *buf, int val)` [Built-in Function]

This function restores the stack context in *buf*, saved by a previous call to `__builtin_setjmp`. After `__builtin_longjmp` is finished, the program resumes execution as if the matching `__builtin_setjmp` returns the value *val*, which must be 1.

Because `__builtin_longjmp` depends on the function return mechanism to restore the stack context, it cannot be called from the same function calling `__builtin_setjmp` to initialize *buf*. It can only be called from a function called (directly or indirectly) from the function calling `__builtin_setjmp`.

7.5 Constructing Function Calls

Using the built-in functions described below, you can record the arguments a function received, and call another function with the same arguments, without knowing the number or types of the arguments.

You can also record the return value of that function call, and later return that value, without knowing what data type the function tried to return (as long as your caller expects that data type).

However, these built-in functions may interact badly with some sophisticated features or other extensions of the language. It is, therefore, not recommended to use them outside very simple functions acting as mere forwarders for their arguments.

`void * __builtin_apply_args ()` [Built-in Function]

This built-in function returns a pointer to data describing how to perform a call with the same arguments as are passed to the current function.

The function saves the arg pointer register, structure value address, and all registers that might be used to pass arguments to a function into a block of memory allocated on the stack. Then it returns the address of that block.

`void * __builtin_apply (void (*function)(), void *arguments, size_t size)` [Built-in Function]

This built-in function invokes *function* with a copy of the parameters described by *arguments* and *size*.

The value of *arguments* should be the value returned by `__builtin_apply_args`. The argument *size* specifies the size of the stack argument data, in bytes.

This function returns a pointer to data describing how to return whatever value is returned by *function*. The data is saved in a block of memory allocated on the stack.

It is not always simple to compute the proper value for *size*. The value is used by `__builtin_apply` to compute the amount of data that should be pushed on the stack and copied from the incoming argument area.

`void __builtin_return (void *result)` [Built-in Function]

This built-in function returns the value described by *result* from the containing function. You should specify, for *result*, a value returned by `__builtin_apply`.

`__builtin_va_arg_pack ()` [Built-in Function]

This built-in function represents all anonymous arguments of an inline function. It can be used only in inline functions that are always inlined, never compiled as a separate function, such as those using `__attribute__ ((__always_inline__))` or `__attribute__ ((__gnu_inline__))` extern inline functions. It must be only passed as last argument to some other function with variable arguments. This is useful for writing small wrapper inlines for variable argument functions, when using preprocessor macros is undesirable. For example:

```
extern int myprintf (FILE *f, const char *format, ...);
extern inline __attribute__ ((__gnu_inline__)) int
myprintf (FILE *f, const char *format, ...)
{
  int r = fprintf (f, "myprintf: ");
  if (r < 0)
    return r;
  int s = fprintf (f, format, __builtin_va_arg_pack ());
  if (s < 0)
    return s;
  return r + s;
}
```

`int __builtin_va_arg_pack_len ()` [Built-in Function]

This built-in function returns the number of anonymous arguments of an inline function. It can be used only in inline functions that are always inlined, never compiled as a separate function, such as those using `__attribute__ ((__always_inline__))` or `__attribute__ ((__gnu_inline__))` extern inline functions. For example following does link- or run-time checking of open arguments for optimized code:

```
#ifdef __OPTIMIZE__
extern inline __attribute__((__gnu_inline__)) int
myopen (const char *path, int oflag, ...)
{
  if (__builtin_va_arg_pack_len () > 1)
    warn_open_too_many_arguments ();

  if (__builtin_constant_p (oflag))
    {
      if ((oflag & O_CREAT) != 0 && __builtin_va_arg_pack_len () < 1)
        {
          warn_open_missing_mode ();
          return __open_2 (path, oflag);
        }
      return open (path, oflag, __builtin_va_arg_pack ());
    }

  if (__builtin_va_arg_pack_len () < 1)
    return __open_2 (path, oflag);

  return open (path, oflag, __builtin_va_arg_pack ());
}
#endif
```

type `__builtin_call_with_static_chain` (*call_exp*, *pointer_exp*) [Built-in Function]

The *call_exp* expression must be a function call, and the *pointer_exp* expression must be a pointer. The *pointer_exp* is passed to the function call in the target's static chain location. The result of builtin is the result of the function call.

Note: This builtin is only available for C. This builtin can be used to call Go closures from C.

7.6 Getting the Return or Frame Address of a Function

These functions may be used to get information about the callers of a function.

`void * __builtin_return_address (unsigned int` *level*`)` [Built-in Function]

This function returns the return address of the current function, or of one of its callers. The *level* argument is number of frames to scan up the call stack. A value of `0` yields the return address of the current function, a value of `1` yields the return address of the caller of the current function, and so forth. When inlining the expected behavior is that the function returns the address of the function that is returned to. To work around this behavior use the `noinline` function attribute.

The *level* argument must be a constant integer.

On some machines it may be impossible to determine the return address of any function other than the current one; in such cases, or when the top of the stack has been reached, this function returns an unspecified value. In addition, `__builtin_frame_address` may be used to determine if the top of the stack has been reached.

Additional post-processing of the returned value may be needed, see `__builtin_extract_return_addr`.

The stored representation of the return address in memory may be different from the address returned by `__builtin_return_address`. For example, on AArch64 the stored address may be mangled with return address signing whereas the address returned by `__builtin_return_address` is not.

Calling this function with a nonzero argument can have unpredictable effects, including crashing the calling program. As a result, calls that are considered unsafe are diagnosed when the `-Wframe-address` option is in effect. Such calls should only be made in debugging situations.

On targets where code addresses are representable as `void *`,

```
void *addr = __builtin_extract_return_addr (__builtin_return_address (0));
```

gives the code address where the current function would return. For example, such an address may be used with `dladdr` or other interfaces that work with code addresses.

`void * __builtin_extract_return_addr (void *`*addr*`)` [Built-in Function]

The address as returned by `__builtin_return_address` may have to be fed through this function to get the actual encoded address. For example, on the 31-bit S/390 platform the highest bit has to be masked out, or on SPARC platforms an offset has to be added for the true next instruction to be executed.

If no fixup is needed, this function simply passes through *addr*.

`void * __builtin_frob_return_addr (void *`*addr*`)` [Built-in Function]

This function does the reverse of `__builtin_extract_return_addr`.

`void * __builtin_frame_address (unsigned int` *level*`)` [Built-in Function]

This function is similar to `__builtin_return_address`, but it returns the address of the function frame rather than the return address of the function. Calling `__builtin_frame_address` with a value of `0` yields the frame address of the current function, a value of `1` yields the frame address of the caller of the current function, and so forth.

The frame is the area on the stack that holds local variables and saved registers. The frame address is normally the address of the first word pushed on to the stack by the function. However, the exact definition depends upon the processor and the calling convention. If the processor has a dedicated frame pointer register, and the function has a frame, then `__builtin_frame_address` returns the value of the frame pointer register.

On some machines it may be impossible to determine the frame address of any function other than the current one; in such cases, or when the top of the stack has been reached, this function returns `0` if the first frame pointer is properly initialized by the startup code.

Calling this function with a nonzero argument can have unpredictable effects, including crashing the calling program. As a result, calls that are considered unsafe are diagnosed when the `-Wframe-address` option is in effect. Such calls should only be made in debugging situations.

`void * __builtin_stack_address ()` [Built-in Function]

This function returns the stack pointer register, offset by `STACK_ADDRESS_OFFSET` if that's defined.

Conceptually, the returned address returned by this built-in function is the boundary between the stack area allocated for use by its caller, and the area that could be modified by a function call, that the caller could safely zero-out before or after (but not during) the call sequence.

Arguments for a callee may be preallocated as part of the caller's stack frame, or allocated on a per-call basis, depending on the target, so they may be on either side of this boundary.

Even if the stack pointer is biased, the result is not. The register save area on SPARC is regarded as modifiable by calls, rather than as allocated for use by the caller function, since it is never in use while the caller function itself is running.

Red zones that only leaf functions could use are also regarded as modifiable by calls, rather than as allocated for use by the caller. This is only theoretical, since leaf functions do not issue calls, but a constant offset makes this built-in function more predictable.

7.7 Stack scrubbing internal interfaces

Stack scrubbing involves cooperation between a `strub` context, i.e., a function whose stack frame is to be zeroed-out, and its callers. The caller initializes a stack watermark, the `strub` context updates the watermark according to its stack use, and the caller zeroes it out once it regains control, whether by the callee's returning or by an exception.

Each of these steps is performed by a different builtin function call. Calls to these builtins are introduced automatically, in response to `strub` attributes and command-line options; they are not expected to be explicitly called by source code.

The functions that implement the builtins are available in libgcc but, depending on optimization levels, they are expanded internally, adjusted to account for inlining, and sometimes combined/deferred (e.g. passing the caller-supplied watermark on to callees, refraining from erasing stack areas that the caller will) to enable tail calls and to optimize for code size.

`void __builtin___strub_enter (void **`*wmptr*`)` [Built-in Function]

This function initializes a stack *watermark* variable with the current top of the stack. A call to this builtin function is introduced before entering a `strub` context. It remains as a function call if optimization is not enabled.

`void __builtin___strub_update (void **`*wmptr*`)` [Built-in Function]

This function updates a stack *watermark* variable with the current top of the stack, if it tops the previous watermark. A call to this builtin function is inserted within `strub` contexts, whenever additional stack space may have been used. It remains as a function call at optimization levels lower than 2.

`void __builtin___strub_leave (void **`*wmptr*`)` [Built-in Function]

This function overwrites the memory area between the current top of the stack, and the *watermark*ed address. A call to this builtin function is inserted after leaving a `strub` context. It remains as a function call at optimization levels lower than 3, and it is guarded by a condition at level 2.

7.8 Using Vector Instructions through Built-in Functions

On some targets, the instruction set contains SIMD vector instructions which operate on multiple values contained in one large register at the same time. For example, on the x86 the MMX, 3DNow! and SSE extensions can be used this way.

The first step in using these extensions is to provide the necessary data types. This should be done using an appropriate `typedef`:

```
typedef int v4si __attribute__ ((vector_size (16)));
```

The `int` type specifies the *base type* (which can be a `typedef`), while the attribute specifies the vector size for the variable, measured in bytes. For example, the declaration above causes the compiler to set the mode for the `v4si` type to be 16 bytes wide and divided into `int` sized units. For a 32-bit `int` this means a vector of 4 units of 4 bytes, and the corresponding mode of `foo` is V4SI.

The `vector_size` attribute is only applicable to integral and floating scalars, although arrays, pointers, and function return values are allowed in conjunction with this construct. Only sizes that are positive power-of-two multiples of the base type size are currently allowed.

All the basic integer types can be used as base types, both as signed and as unsigned: `char`, `short`, `int`, `long`, `long long`. In addition, `float` and `double` can be used to build floating-point vector types.

Specifying a combination that is not valid for the current architecture causes GCC to synthesize the instructions using a narrower mode. For example, if you specify a variable of type `V4SI` and your architecture does not allow for this specific SIMD type, GCC produces code that uses 4 `SIs`.

The types defined in this manner can be used with a subset of normal C operations. Currently, GCC allows using the following operators on these types: `+, -, *, /, unary minus, ^, |, &, ~, %`.

The operations behave like C++ `valarrays`. Addition is defined as the addition of the corresponding elements of the operands. For example, in the code below, each of the 4 elements in *a* is added to the corresponding 4 elements in *b* and the resulting vector is stored in *c*.

```
typedef int v4si __attribute__ ((vector_size (16)));

v4si a, b, c;

c = a + b;
```

Subtraction, multiplication, division, and the logical operations operate in a similar manner. Likewise, the result of using the unary minus or complement operators on a vector type is a vector whose elements are the negative or complemented values of the corresponding elements in the operand.

It is possible to use shifting operators `<<`, `>>` on integer-type vectors. The operation is defined as following: `{a0, a1, ..., an} >> {b0, b1, ..., bn} == {a0 >> b0, a1 >> b1,`

..., an >> bn}. Unlike OpenCL, values of b are not implicitly taken modulo bit width of the base type B, and the behavior is undefined if any bi is greater than or equal to B.

In contrast to scalar operations in C and C++, operands of integer vector operations do not undergo integer promotions.

Operands of binary vector operations must have the same number of elements.

For convenience, it is allowed to use a binary vector operation where one operand is a scalar. In that case the compiler transforms the scalar operand into a vector where each element is the scalar from the operation. The transformation happens only if the scalar could be safely converted to the vector-element type. Consider the following code.

```
typedef int v4si __attribute__ ((vector_size (16)));

v4si a, b, c;
long l;

a = b + 1;    /* a = b + {1,1,1,1}; */
a = 2 * b;    /* a = {2,2,2,2} * b; */

a = l + a;    /* Error, cannot convert long to int. */
```

Vectors can be subscripted as if the vector were an array with the same number of elements and base type. Out of bound accesses invoke undefined behavior at run time. Warnings for out of bound accesses for vector subscription can be enabled with -Warray-bounds.

Vector comparison is supported with standard comparison operators: ==, !=, <, <=, >, and >=. Comparison operands can be vector expressions of integer-type or real-type. Comparison between integer-type vectors and real-type vectors are not supported. The result of the comparison is a vector of the same width and number of elements as the comparison operands with a signed integral element type.

Vectors are compared elementwise producing 0 when the comparison is false and -1 (a constant of the appropriate type where all bits are set) otherwise. Consider the following example:

```
typedef int v4si __attribute__ ((vector_size (16)));

v4si a = {1,2,3,4};
v4si b = {3,2,1,4};
v4si c;

c = a >  b;     /* The result would be {0, 0,-1, 0}  */
c = a == b;     /* The result would be {0,-1, 0,-1}  */
```

In C++, the ternary operator ?: is available. a?b:c, where b and c are vectors of the same type and a is an integer vector with the same number of elements of the same size as b and c, computes all three arguments and creates a vector {a[0]?b[0]:c[0], a[1]?b[1]:c[1], ...}. Note that unlike in OpenCL, a is thus interpreted as a != 0 and not a < 0. As in the case of binary operations, this syntax is also accepted when one of b or c is a scalar that is then transformed into a vector. If both b and c are scalars and the type of true?b:c has the same size as the element type of a, then b and c are converted to a vector type whose elements have this type and with the same number of elements as a.

In C++, the logic operators !, &&, || are available for vectors. !v is equivalent to v == 0, a && b is equivalent to a!=0 & b!=0 and a || b is equivalent to a!=0 | b!=0. For mixed operations between a scalar `s` and a vector `v`, `s && v` is equivalent to `s?v!=0:0` (the evaluation is short-circuit) and `v && s` is equivalent to `v!=0 & (s?-1:0)`.

Vector shuffling is available using functions `__builtin_shuffle (vec, mask)` and `__builtin_shuffle (vec0, vec1, mask)`. Both functions construct a permutation of elements from one or two vectors and return a vector of the same type as the input vector(s). The *mask* is an integral vector with the same width (W) and element count (N) as the output vector.

The elements of the input vectors are numbered in memory ordering of *vec0* beginning at 0 and *vec1* beginning at N. The elements of *mask* are considered modulo N in the single-operand case and modulo $2 * N$ in the two-operand case.

Consider the following example,

```
typedef int v4si __attribute__ ((vector_size (16)));

v4si a = {1,2,3,4};
v4si b = {5,6,7,8};
v4si mask1 = {0,1,1,3};
v4si mask2 = {0,4,2,5};
v4si res;

res = __builtin_shuffle (a, mask1);       /* res is {1,2,2,4}  */
res = __builtin_shuffle (a, b, mask2);    /* res is {1,5,3,6}  */
```

Note that `__builtin_shuffle` is intentionally semantically compatible with the OpenCL `shuffle` and `shuffle2` functions.

You can declare variables and use them in function calls and returns, as well as in assignments and some casts. You can specify a vector type as a return type for a function. Vector types can also be used as function arguments. It is possible to cast from one vector type to another, provided they are of the same size (in fact, you can also cast vectors to and from other data types of the same size).

You cannot operate between vectors of different lengths or different signedness without a cast.

Vector shuffling is available using the `__builtin_shufflevector (vec1, vec2, index...)` function. *vec1* and *vec2* must be expressions with vector type with a compatible element type. The result of `__builtin_shufflevector` is a vector with the same element type as *vec1* and *vec2* but that has an element count equal to the number of indices specified.

The *index* arguments are a list of integers that specify the elements indices of the first two vectors that should be extracted and returned in a new vector. These element indices are numbered sequentially starting with the first vector, continuing into the second vector. An index of -1 can be used to indicate that the corresponding element in the returned vector is a don't care and can be freely chosen to optimized the generated code sequence performing the shuffle operation.

Consider the following example,

```
typedef int v4si __attribute__ ((vector_size (16)));
typedef int v8si __attribute__ ((vector_size (32)));

v8si a = {1,-2,3,-4,5,-6,7,-8};
v4si b = __builtin_shufflevector (a, a, 0, 2, 4, 6); /* b is {1,3,5,7} */
v4si c = {-2,-4,-6,-8};
```

```
v8si d = __builtin_shufflevector (c, b, 4, 0, 5, 1, 6, 2, 7, 3); /* d is a */
```

Vector conversion is available using the `__builtin_convertvector (vec, vectype)` function. *vec* must be an expression with integral or floating vector type and *vectype* an integral or floating vector type with the same number of elements. The result has *vectype* type and value of a C cast of every element of *vec* to the element type of *vectype*.

Consider the following example,

```
typedef int v4si __attribute__ ((vector_size (16)));
typedef float v4sf __attribute__ ((vector_size (16)));
typedef double v4df __attribute__ ((vector_size (32)));
typedef unsigned long long v4di __attribute__ ((vector_size (32)));

v4si a = {1,-2,3,-4};
v4sf b = {1.5f,-2.5f,3.f,7.f};
v4di c = {1ULL,5ULL,0ULL,10ULL};
v4sf d = __builtin_convertvector (a, v4sf); /* d is {1.f,-2.f,3.f,-4.f} */
/* Equivalent of:
   v4sf d = { (float)a[0], (float)a[1], (float)a[2], (float)a[3] }; */
v4df e = __builtin_convertvector (a, v4df); /* e is {1.,-2.,3.,-4.} */
v4df f = __builtin_convertvector (b, v4df); /* f is {1.5,-2.5,3.,7.} */
v4si g = __builtin_convertvector (f, v4si); /* g is {1,-2,3,7} */
v4si h = __builtin_convertvector (c, v4si); /* h is {1,5,0,10} */
```

Sometimes it is desirable to write code using a mix of generic vector operations (for clarity) and machine-specific vector intrinsics (to access vector instructions that are not exposed via generic built-ins). On x86, intrinsic functions for integer vectors typically use the same vector type `__m128i` irrespective of how they interpret the vector, making it necessary to cast their arguments and return values from/to other vector types. In C, you can make use of a `union` type:

```
#include <immintrin.h>

typedef unsigned char u8x16 __attribute__ ((vector_size (16)));
typedef unsigned int  u32x4 __attribute__ ((vector_size (16)));

typedef union {
        __m128i mm;
        u8x16   u8;
        u32x4   u32;
} v128;
```

for variables that can be used with both built-in operators and x86 intrinsics:

```
v128 x, y = { 0 };
memcpy (&x, ptr, sizeof x);
y.u8  += 0x80;
x.mm  = _mm_adds_epu8 (x.mm, y.mm);
x.u32 &= 0xffffff;

/* Instead of a variable, a compound literal may be used to pass the
   return value of an intrinsic call to a function expecting the union: */
v128 foo (v128);
x = foo ((v128) {_mm_adds_epu8 (x.mm, y.mm)});
```

7.9 Builtins for Atomic Memory Access

GCC supports two sets of builtins for atomic memory access primitives. The `__atomic` builtins provide the underlying support for the C++11 atomic operations library, and are the currently-recommended interface when the C++11 library functions cannot be used directly. The `__sync` builtins implement the specification from the Intel IA64 pSABI and are supported primarily for use in legacy code.

7.9.1 Built-in Functions for Memory Model Aware Atomic Operations

The following built-in functions approximately match the requirements for the C++11 memory model. They are all identified by being prefixed with '`__atomic`' and most are overloaded so that they work with multiple types.

These functions are intended to replace the legacy '`__sync`' builtins. The main difference is that the memory order that is requested is a parameter to the functions. New code should always use the '`__atomic`' builtins rather than the '`__sync`' builtins.

Note that the '`__atomic`' builtins assume that programs will conform to the C++11 memory model. In particular, they assume that programs are free of data races. See the C++11 standard for detailed requirements.

The '`__atomic`' builtins can be used with any integral scalar or pointer type that is 1, 2, 4, or 8 bytes in length. 16-byte integral types are also allowed if '`__int128`' (see Section 6.1.1 [__int128], page 603) is supported by the architecture.

The four non-arithmetic functions (load, store, exchange, and compare_exchange) all have a generic version as well. This generic version works on any data type. It uses the lock-free built-in function if the specific data type size makes that possible; otherwise, an external call is left to be resolved at run time. This external call is the same format with the addition of a '`size_t`' parameter inserted as the first parameter indicating the size of the object being pointed to. All objects must be the same size.

There are 6 different memory orders that can be specified. These map to the C++11 memory orders with the same names, see the C++11 standard or the GCC wiki on atomic synchronization (`https://gcc.gnu.org/wiki/Atomic/GCCMM/AtomicSync`) for detailed definitions. Individual targets may also support additional memory orders for use on specific architectures. Refer to the target documentation for details of these.

An atomic operation can both constrain code motion and be mapped to hardware instructions for synchronization between threads (e.g., a fence). To which extent this happens is controlled by the memory orders, which are listed here in approximately ascending order of strength. The description of each memory order is only meant to roughly illustrate the effects and is not a specification; see the C++11 memory model for precise semantics.

`__ATOMIC_RELAXED`
: Implies no inter-thread ordering constraints.

`__ATOMIC_CONSUME`
: This is currently implemented using the stronger `__ATOMIC_ACQUIRE` memory order because of a deficiency in C++11's semantics for `memory_order_consume`.

`__ATOMIC_ACQUIRE`
: Creates an inter-thread happens-before constraint from the release (or stronger) semantic store to this acquire load. Can prevent hoisting of code to before the operation.

`__ATOMIC_RELEASE`
: Creates an inter-thread happens-before constraint to acquire (or stronger) semantic loads that read from this release store. Can prevent sinking of code to after the operation.

`__ATOMIC_ACQ_REL`
: Combines the effects of both `__ATOMIC_ACQUIRE` and `__ATOMIC_RELEASE`.

`__ATOMIC_SEQ_CST`
: Enforces total ordering with all other `__ATOMIC_SEQ_CST` operations.

Note that in the C++11 memory model, *fences* (e.g., '`__atomic_thread_fence`') take effect in combination with other atomic operations on specific memory locations (e.g., atomic loads); operations on specific memory locations do not necessarily affect other operations in the same way.

Target architectures are encouraged to provide their own patterns for each of the atomic built-in functions. If no target is provided, the original non-memory model set of '`__sync`' atomic built-in functions are used, along with any required synchronization fences surrounding it in order to achieve the proper behavior. Execution in this case is subject to the same restrictions as those built-in functions.

If there is no pattern or mechanism to provide a lock-free instruction sequence, a call is made to an external routine with the same parameters to be resolved at run time.

When implementing patterns for these built-in functions, the memory order parameter can be ignored as long as the pattern implements the most restrictive `__ATOMIC_SEQ_CST` memory order. Any of the other memory orders execute correctly with this memory order but they may not execute as efficiently as they could with a more appropriate implementation of the relaxed requirements.

Note that the C++11 standard allows for the memory order parameter to be determined at run time rather than at compile time. These built-in functions map any run-time value to `__ATOMIC_SEQ_CST` rather than invoke a runtime library call or inline a switch statement. This is standard compliant, safe, and the simplest approach for now.

The memory order parameter is a signed int, but only the lower 16 bits are reserved for the memory order. The remainder of the signed int is reserved for target use and should be 0. Use of the predefined atomic values ensures proper usage.

The x86 architecture supports additional memory ordering modifiers to mark critical sections for hardware lock elision. These modifiers can be bitwise or'ed with a standard memory order to atomic intrinsics.

`__ATOMIC_HLE_ACQUIRE`
: Start lock elision on a lock variable. Memory order must be `__ATOMIC_ACQUIRE` or stronger.

`__ATOMIC_HLE_RELEASE`
: End lock elision on a lock variable. Memory order must be `__ATOMIC_RELEASE` or stronger.

When a lock acquire fails, it is required for good performance to abort the transaction quickly. This can be done with a `_mm_pause`.

```
#include <immintrin.h> // For _mm_pause
```

```
int lockvar;

/* Acquire lock with lock elision */
while (__atomic_exchange_n(&lockvar, 1, __ATOMIC_ACQUIRE|__ATOMIC_HLE_ACQUIRE))
    _mm_pause(); /* Abort failed transaction */
...
/* Free lock with lock elision */
__atomic_store_n(&lockvar, 0, __ATOMIC_RELEASE|__ATOMIC_HLE_RELEASE);
```

type `__atomic_load_n` (*type *ptr*, `int` *memorder*) [Built-in Function]

This built-in function implements an atomic load operation. It returns the contents of `*ptr`.

The valid memory order variants are `__ATOMIC_RELAXED`, `__ATOMIC_SEQ_CST`, `__ATOMIC_ACQUIRE`, and `__ATOMIC_CONSUME`.

`void __atomic_load` (*type *ptr*, *type *ret*, `int` *memorder*) [Built-in Function]

This is the generic version of an atomic load. It returns the contents of `*ptr` in `*ret`.

`void __atomic_store_n` (*type *ptr*, *type val*, `int` *memorder*) [Built-in Function]

This built-in function implements an atomic store operation. It writes `val` into `*ptr`.

The valid memory order variants are `__ATOMIC_RELAXED`, `__ATOMIC_SEQ_CST`, and `__ATOMIC_RELEASE`.

`void __atomic_store` (*type *ptr*, *type *val*, `int` *memorder*) [Built-in Function]

This is the generic version of an atomic store. It stores the value of `*val` into `*ptr`.

type `__atomic_exchange_n` (*type *ptr*, *type val*, `int` *memorder*) [Built-in Function]

This built-in function implements an atomic exchange operation. It writes *val* into `*ptr`, and returns the previous contents of `*ptr`.

All memory order variants are valid.

`void __atomic_exchange` (*type *ptr*, *type *val*, *type *ret*, `int` *memorder*) [Built-in Function]

This is the generic version of an atomic exchange. It stores the contents of `*val` into `*ptr`. The original value of `*ptr` is copied into `*ret`.

`bool __atomic_compare_exchange_n` (*type *ptr*, *type *expected*, *type desired*, `bool` *weak*, `int` *success_memorder*, `int` *failure_memorder*) [Built-in Function]

This built-in function implements an atomic compare and exchange operation. This compares the contents of `*ptr` with the contents of `*expected`. If equal, the operation is a *read-modify-write* operation that writes *desired* into `*ptr`. If they are not equal, the operation is a *read* and the current contents of `*ptr` are written into `*expected`. *weak* is `true` for weak compare_exchange, which may fail spuriously, and `false` for the strong variation, which never fails spuriously. Many targets only offer the strong variation and ignore the parameter. When in doubt, use the strong variation.

If *desired* is written into `*ptr` then `true` is returned and memory is affected according to the memory order specified by *success_memorder*. There are no restrictions on what memory order can be used here.

Otherwise, `false` is returned and memory is affected according to *failure_memorder*. This memory order cannot be `__ATOMIC_RELEASE` nor `__ATOMIC_ACQ_REL`. It also cannot be a stronger order than that specified by *success_memorder*.

`bool __atomic_compare_exchange (type *ptr, type *expected, type *desired, bool weak, int success_memorder, int failure_memorder)` [Built-in Function]

This built-in function implements the generic version of `__atomic_compare_exchange`. The function is virtually identical to `__atomic_compare_exchange_n`, except the desired value is also a pointer.

`type __atomic_add_fetch (type *ptr, type val, int memorder)` [Built-in Function]
`type __atomic_sub_fetch (type *ptr, type val, int memorder)` [Built-in Function]
`type __atomic_and_fetch (type *ptr, type val, int memorder)` [Built-in Function]
`type __atomic_xor_fetch (type *ptr, type val, int memorder)` [Built-in Function]
`type __atomic_or_fetch (type *ptr, type val, int memorder)` [Built-in Function]
`type __atomic_nand_fetch (type *ptr, type val, int memorder)` [Built-in Function]

These built-in functions perform the operation suggested by the name, and return the result of the operation. Operations on pointer arguments are performed as if the operands were of the `uintptr_t` type. That is, they are not scaled by the size of the type to which the pointer points.

```
{ *ptr op= val; return *ptr; }
{ *ptr = ~(*ptr & val); return *ptr; } // nand
```

The object pointed to by the first argument must be of integer or pointer type. It must not be a boolean type. All memory orders are valid.

`type __atomic_fetch_add (type *ptr, type val, int memorder)` [Built-in Function]
`type __atomic_fetch_sub (type *ptr, type val, int memorder)` [Built-in Function]
`type __atomic_fetch_and (type *ptr, type val, int memorder)` [Built-in Function]
`type __atomic_fetch_xor (type *ptr, type val, int memorder)` [Built-in Function]
`type __atomic_fetch_or (type *ptr, type val, int memorder)` [Built-in Function]

type `__atomic_fetch_nand` (*type* **ptr*, *type* *val*, `int` *memorder*) [Built-in Function]

These built-in functions perform the operation suggested by the name, and return the value that had previously been in `*ptr`. Operations on pointer arguments are performed as if the operands were of the `uintptr_t` type. That is, they are not scaled by the size of the type to which the pointer points.

```
{ tmp = *ptr; *ptr op= val; return tmp; }
{ tmp = *ptr; *ptr = ~(*ptr & val); return tmp; } // nand
```

The same constraints on arguments apply as for the corresponding `__atomic_op_fetch` built-in functions. All memory orders are valid.

`bool __atomic_test_and_set (void *ptr, int memorder)` [Built-in Function]

This built-in function performs an atomic test-and-set operation on the byte at `*ptr`. The byte is set to some implementation defined nonzero "set" value and the return value is `true` if and only if the previous contents were "set". It should be only used for operands of type `bool` or `char`. For other types only part of the value may be set.

All memory orders are valid.

`void __atomic_clear (bool *ptr, int memorder)` [Built-in Function]

This built-in function performs an atomic clear operation on `*ptr`. After the operation, `*ptr` contains 0. It should be only used for operands of type `bool` or `char` and in conjunction with `__atomic_test_and_set`. For other types it may only clear partially. If the type is not `bool` prefer using `__atomic_store`.

The valid memory order variants are `__ATOMIC_RELAXED`, `__ATOMIC_SEQ_CST`, and `__ATOMIC_RELEASE`.

`void __atomic_thread_fence (int memorder)` [Built-in Function]

This built-in function acts as a synchronization fence between threads based on the specified memory order.

All memory orders are valid.

`void __atomic_signal_fence (int memorder)` [Built-in Function]

This built-in function acts as a synchronization fence between a thread and signal handlers based in the same thread.

All memory orders are valid.

`bool __atomic_always_lock_free (size_t size, void *ptr)` [Built-in Function]

This built-in function returns `true` if objects of *size* bytes always generate lock-free atomic instructions for the target architecture. *size* must resolve to a compile-time constant and the result also resolves to a compile-time constant.

ptr is an optional pointer to the object that may be used to determine alignment. A value of 0 indicates typical alignment should be used. The compiler may also ignore this parameter.

```
if (__atomic_always_lock_free (sizeof (long long), 0))
```

`bool __atomic_is_lock_free (size_t size, void *ptr)` [Built-in Function]

This built-in function returns `true` if objects of *size* bytes always generate lock-free atomic instructions for the target architecture. If the built-in function is not known to be lock-free, a call is made to a runtime routine named `__atomic_is_lock_free`.

ptr is an optional pointer to the object that may be used to determine alignment. A value of 0 indicates typical alignment should be used. The compiler may also ignore this parameter.

7.9.2 Legacy __sync Built-in Functions for Atomic Memory Access

The following built-in functions are intended to be compatible with those described in the *Intel Itanium Processor-specific Application Binary Interface*, section 7.4. As such, they depart from normal GCC practice by not using the '`__builtin_`' prefix and also by being overloaded so that they work on multiple types.

The definition given in the Intel documentation allows only for the use of the types `int`, `long`, `long long` or their unsigned counterparts. GCC allows any scalar type that is 1, 2, 4 or 8 bytes in size other than the C type `_Bool` or the C++ type `bool`. Operations on pointer arguments are performed as if the operands were of the `uintptr_t` type. That is, they are not scaled by the size of the type to which the pointer points.

These functions are implemented in terms of the '`__atomic`' builtins (see Section 7.9.1 [__atomic Builtins], page 854). They should not be used for new code which should use the '`__atomic`' builtins instead.

Not all operations are supported by all target processors. If a particular operation cannot be implemented on the target processor, a call to an external function is generated. The external function carries the same name as the built-in version, with an additional suffix '`_n`' where *n* is the size of the data type.

In most cases, these built-in functions are considered a *full barrier*. That is, no memory operand is moved across the operation, either forward or backward. Further, instructions are issued as necessary to prevent the processor from speculating loads across the operation and from queuing stores after the operation.

All of the routines are described in the Intel documentation to take "an optional list of variables protected by the memory barrier". It's not clear what is meant by that; it could mean that *only* the listed variables are protected, or it could mean a list of additional variables to be protected. The list is ignored by GCC which treats it as empty. GCC interprets an empty list as meaning that all globally accessible variables should be protected.

`type __sync_fetch_and_add (type *ptr, type value, ...)` [Built-in Function]

`type __sync_fetch_and_sub (type *ptr, type value, ...)` [Built-in Function]

`type __sync_fetch_and_or (type *ptr, type value, ...)` [Built-in Function]

`type __sync_fetch_and_and (type *ptr, type value, ...)` [Built-in Function]

`type __sync_fetch_and_xor (type *ptr, type value, ...)` [Built-in Function] *type* `__sync_fetch_and_nand` (*type *ptr*, *type value*, ...) [Built-in Function]

These built-in functions perform the operation suggested by the name, and returns the value that had previously been in memory. That is, operations on integer operands have the following semantics. Operations on pointer arguments are performed as if the operands were of the `uintptr_t` type. That is, they are not scaled by the size of the type to which the pointer points.

```
{ tmp = *ptr; *ptr op= value; return tmp; }
{ tmp = *ptr; *ptr = ~(tmp & value); return tmp; }   // nand
```

The object pointed to by the first argument must be of integer or pointer type. It must not be a boolean type.

Note: GCC 4.4 and later implement `__sync_fetch_and_nand` as `*ptr = ~(tmp & value)` instead of `*ptr = ~tmp & value`.

type `__sync_add_and_fetch` (*type *ptr*, *type value*, ...) [Built-in Function]

type `__sync_sub_and_fetch` (*type *ptr*, *type value*, ...) [Built-in Function]

type `__sync_or_and_fetch` (*type *ptr*, *type value*, ...) [Built-in Function]

type `__sync_and_and_fetch` (*type *ptr*, *type value*, ...) [Built-in Function]

type `__sync_xor_and_fetch` (*type *ptr*, *type value*, ...) [Built-in Function]

type `__sync_nand_and_fetch` (*type *ptr*, *type value*, ...) [Built-in Function]

These built-in functions perform the operation suggested by the name, and return the new value. That is, operations on integer operands have the following semantics. Operations on pointer operands are performed as if the operand's type were `uintptr_t`.

```
{ *ptr op= value; return *ptr; }
{ *ptr = ~(*ptr & value); return *ptr; }   // nand
```

The same constraints on arguments apply as for the corresponding `__sync_op_and_fetch` built-in functions.

Note: GCC 4.4 and later implement `__sync_nand_and_fetch` as `*ptr = ~(*ptr & value)` instead of `*ptr = ~*ptr & value`.

`bool __sync_bool_compare_and_swap` (*type *ptr*, *type oldval*, *type newval*, ...) [Built-in Function]

type `__sync_val_compare_and_swap` (*type *ptr*, *type oldval*, *type newval*, ...) [Built-in Function]

These built-in functions perform an atomic compare and swap. That is, if the current value of **ptr* is *oldval*, then write *newval* into **ptr*.

The "bool" version returns `true` if the comparison is successful and *newval* is written. The "val" version returns the contents of **ptr* before the operation.

`void __sync_synchronize (...)` [Built-in Function]

This built-in function issues a full memory barrier.

`type __sync_lock_test_and_set (type *ptr, type value, ...)` [Built-in Function]

This built-in function, as described by Intel, is not a traditional test-and-set operation, but rather an atomic exchange operation. It writes *value* into `*ptr`, and returns the previous contents of `*ptr`.

Many targets have only minimal support for such locks, and do not support a full exchange operation. In this case, a target may support reduced functionality here by which the *only* valid value to store is the immediate constant 1. The exact value actually stored in `*ptr` is implementation defined.

This built-in function is not a full barrier, but rather an *acquire barrier*. This means that references after the operation cannot move to (or be speculated to) before the operation, but previous memory stores may not be globally visible yet, and previous memory loads may not yet be satisfied.

`void __sync_lock_release (type *ptr, ...)` [Built-in Function]

This built-in function releases the lock acquired by `__sync_lock_test_and_set`. Normally this means writing the constant 0 to `*ptr`.

This built-in function is not a full barrier, but rather a *release barrier*. This means that all previous memory stores are globally visible, and all previous memory loads have been satisfied, but following memory reads are not prevented from being speculated to before the barrier.

7.10 Object Size Checking

7.10.1 Object Size Checking Built-in Functions

GCC implements a limited buffer overflow protection mechanism that can prevent some buffer overflow attacks by determining the sizes of objects into which data is about to be written and preventing the writes when the size isn't sufficient. The built-in functions described below yield the best results when used together and when optimization is enabled. For example, to detect object sizes across function boundaries or to follow pointer assignments through non-trivial control flow they rely on various optimization passes enabled with `-O2`. However, to a limited extent, they can be used without optimization as well.

`size_t __builtin_object_size (const void * ptr, int type)` [Built-in Function]

This built-in construct returns a constant number of bytes from *ptr* to the end of the object *ptr* pointer points to (if known at compile time). To determine the sizes of dynamically allocated objects the function relies on the allocation functions called to obtain the storage to be declared with the `alloc_size` attribute (see Section 6.4.1.1 [Common Function Attributes], page 622). `__builtin_object_size` never evaluates its arguments for side effects. If there are any side effects in them, it returns `(size_t) -1` for *type* 0 or 1 and `(size_t) 0` for *type* 2 or 3. If there are multiple objects *ptr* can point to and all of them are known at compile time, the returned number is the maximum of remaining byte counts in those objects if *type* & 2 is 0 and minimum if nonzero. If it is not possible to determine which objects *ptr* points to at compile time, `__builtin_object_size` should return `(size_t) -1` for *type* 0 or 1 and `(size_t) 0` for *type* 2 or 3.

type is an integer constant from 0 to 3. If the least significant bit is clear, objects are whole variables, if it is set, a closest surrounding subobject is considered the object a pointer points to. The second bit determines if maximum or minimum of remaining bytes is computed.

```
struct V { char buf1[10]; int b; char buf2[10]; } var;
char *p = &var.buf1[1];
int *q = &var.b;

/* Here the object p points to is var.  */
assert (__builtin_object_size (p, 0) == sizeof (var) - 1);
/* The subobject p points to is var.buf1.  */
assert (__builtin_object_size (p, 1) == sizeof (var.buf1) - 1);
/* The object q points to is var.  */
assert (__builtin_object_size (q, 0)
        == (char *) (&var + 1) - (char *) &var.b);
/* The subobject q points to is var.b.  */
assert (__builtin_object_size (q, 1) == sizeof (var.b));
```

`size_t __builtin_dynamic_object_size (const void * ptr, int type)` [Built-in Function]

This builtin is similar to `__builtin_object_size` in that it returns a number of bytes from *ptr* to the end of the object *ptr* pointer points to, except that the size returned may not be a constant. This results in successful evaluation of object size estimates in a wider range of use cases and can be more precise than `__builtin_object_size`, but it incurs a performance penalty since it may add a runtime overhead on size computation. Semantics of *type* as well as return values in case it is not possible to determine which objects *ptr* points to at compile time are the same as in the case of `__builtin_object_size`.

7.10.2 Object Size Checking and Source Fortification

Hardening of function calls using the `_FORTIFY_SOURCE` macro is one of the key uses of the object size checking built-in functions. To make implementation of these features more convenient and improve optimization and diagnostics, there are built-in functions added for many common string operation functions, e.g., for `memcpy` `__builtin___memcpy_chk` built-in is provided. This built-in has an additional last argument, which is the number of bytes remaining in the object the *dest* argument points to or `(size_t) -1` if the size is not known.

The built-in functions are optimized into the normal string functions like `memcpy` if the last argument is `(size_t) -1` or if it is known at compile time that the destination object will not be overflowed. If the compiler can determine at compile time that the object will always be overflowed, it issues a warning.

The intended use can be e.g.

```
#undef memcpy
#define bos0(dest) __builtin_object_size (dest, 0)
#define memcpy(dest, src, n) \
  __builtin___memcpy_chk (dest, src, n, bos0 (dest))

char *volatile p;
char buf[10];
/* It is unknown what object p points to, so this is optimized
   into plain memcpy - no checking is possible.  */
```

```
memcpy (p, "abcde", n);
/* Destination is known and length too.  It is known at compile
   time there will be no overflow.  */
memcpy (&buf[5], "abcde", 5);
/* Destination is known, but the length is not known at compile time.
   This will result in __memcpy_chk call that can check for overflow
   at run time.  */
memcpy (&buf[5], "abcde", n);
/* Destination is known and it is known at compile time there will
   be overflow.  There will be a warning and __memcpy_chk call that
   will abort the program at run time.  */
memcpy (&buf[6], "abcde", 5);
```

Such built-in functions are provided for `memcpy`, `mempcpy`, `memmove`, `memset`, `strcpy`, `stpcpy`, `strncpy`, `strcat` and `strncat`.

7.10.2.1 Formatted Output Function Checking

`int __builtin___sprintf_chk (char *`*s*`, int `*flag*`, size_t `*os*`, const char *`*fmt*`, ...)` [Built-in Function]

`int __builtin___snprintf_chk (char *`*s*`, size_t `*maxlen*`, int `*flag*`, size_t `*os*`, const char *`*fmt*`, ...)` [Built-in Function]

`int __builtin___vsprintf_chk (char *`*s*`, int `*flag*`, size_t `*os*`, const char *`*fmt*`, va_list `*ap*`)` [Built-in Function]

`int __builtin___vsnprintf_chk (char *`*s*`, size_t `*maxlen*`, int `*flag*`, size_t `*os*`, const char *`*fmt*`, va_list `*ap*`)` [Built-in Function]

The added *flag* argument is passed unchanged to `__sprintf_chk` etc. functions and can contain implementation specific flags on what additional security measures the checking function might take, such as handling `%n` differently.

The *os* argument is the object size *s* points to, like in the other built-in functions. There is a small difference in the behavior though, if *os* is `(size_t) -1`, the built-in functions are optimized into the non-checking functions only if *flag* is 0, otherwise the checking function is called with *os* argument set to `(size_t) -1`.

In addition to this, there are checking built-in functions `__builtin___printf_chk`, `__builtin___vprintf_chk`, `__builtin___fprintf_chk` and `__builtin___vfprintf_chk`. These have just one additional argument, *flag*, right before format string *fmt*. If the compiler is able to optimize them to `fputc` etc. functions, it does, otherwise the checking function is called and the *flag* argument passed to it.

7.11 Built-in functions for C++ allocations and deallocations

GNU C++ provides builtins that are equivalent to calling `::operator new` or `::operator delete` with the same arguments. It is an error if the selected `::operator new` or `::operator delete` overload is not a replaceable global operator. For optimization purposes, calls to pairs of these builtins can be omitted if access to the allocation is optimized out, or could be replaced with an implementation-provided buffer on the stack, or multiple allocation calls can be merged into a single allocation. In C++ such optimizations are normally allowed just for calls to such replaceable global operators from `new` and `delete` expressions.

```
void foo () {
```

```
    int *a = new int;
    delete a; // This pair of allocation/deallocation operators can be omitted
      // or replaced with int _temp; int *a = &_temp; etc.
    void *b = ::operator new (32);
    ::operator delete (b); // This one cannnot.
    void *c = __builtin_operator_new (32);
    __builtin_operator_delete (c); // This one can.
  }
```

These built-ins are only available in C++.

`void * __builtin_operator_new (std::size_t size, ...)` [Built-in Function]

This is the built-in form of `operator new`. It accepts the same argument forms as a "usual allocation function", as described in the C++ standard.

`void __builtin_operator_delete (void * ptr, ...)` [Built-in Function]

This is the built-in form of `operator delete`. It accepts the same argument forms as a "usual deallocation function", as described in the C++ standard.

7.12 Other Built-in Functions Provided by GCC

This section documents miscellaneous built-in functions available in GCC.

`bool __builtin_has_attribute (type-or-expression, attribute)` [Built-in Function]

The `__builtin_has_attribute` function evaluates to an integer constant expression equal to `true` if the symbol or type referenced by the *type-or-expression* argument has been declared with the *attribute* referenced by the second argument. For an *type-or-expression* argument that does not reference a symbol, since attributes do not apply to expressions the built-in consider the type of the argument. Neither argument is evaluated. The *type-or-expression* argument is subject to the same restrictions as the argument to `typeof` (see Section 6.12.5 [Typeof], page 818). The *attribute* argument is an attribute name optionally followed by a comma-separated list of arguments enclosed in parentheses. Both forms of attribute names—with and without double leading and trailing underscores—are recognized. See Section 6.4.7 [Attribute Syntax], page 734, for details. When no attribute arguments are specified for an attribute that expects one or more arguments the function returns `true` if *type-or-expression* has been declared with the attribute regardless of the attribute argument values. Arguments provided for an attribute that expects some are validated and matched up to the provided number. The function returns `true` if all provided arguments match. For example, the first call to the function below evaluates to `true` because `x` is declared with the `aligned` attribute but the second call evaluates to `false` because `x` is declared `aligned (8)` and not `aligned (4)`.

```
__attribute__ ((aligned (8))) int x;
_Static_assert (__builtin_has_attribute (x, aligned), "aligned");
_Static_assert (!__builtin_has_attribute (x, aligned (4)), "aligned (4)");
```

Due to a limitation the `__builtin_has_attribute` function returns `false` for the `mode` attribute even if the type or variable referenced by the *type-or-expression* argument was declared with one. The function is also not supported with labels, and in C with enumerators.

Note that unlike the `__has_attribute` preprocessor operator which is suitable for use in `#if` preprocessing directives `__builtin_has_attribute` is an intrinsic function that is not recognized in such contexts.

type `__builtin_speculation_safe_value` (*type val*, *type failval*) [Built-in Function]

This built-in function can be used to help mitigate against unsafe speculative execution. *type* may be any integral type or any pointer type.

1. If the CPU is not speculatively executing the code, then *val* is returned.
2. If the CPU is executing speculatively then either:
   - The function may cause execution to pause until it is known that the code is no-longer being executed speculatively (in which case *val* can be returned, as above); or
   - The function may use target-dependent speculation tracking state to cause *failval* to be returned when it is known that speculative execution has incorrectly predicted a conditional branch operation.

The second argument, *failval*, is optional and defaults to zero if omitted.

GCC defines the preprocessor macro `__HAVE_BUILTIN_SPECULATION_SAFE_VALUE` for targets that have been updated to support this builtin.

The built-in function can be used where a variable appears to be used in a safe way, but the CPU, due to speculative execution may temporarily ignore the bounds checks. Consider, for example, the following function:

```
int array[500];
int f (unsigned untrusted_index)
{
  if (untrusted_index < 500)
    return array[untrusted_index];
  return 0;
}
```

If the function is called repeatedly with `untrusted_index` less than the limit of 500, then a branch predictor will learn that the block of code that returns a value stored in `array` will be executed. If the function is subsequently called with an out-of-range value it will still try to execute that block of code first until the CPU determines that the prediction was incorrect (the CPU will unwind any incorrect operations at that point). However, depending on how the result of the function is used, it might be possible to leave traces in the cache that can reveal what was stored at the out-of-bounds location. The built-in function can be used to provide some protection against leaking data in this way by changing the code to:

```
int array[500];
int f (unsigned untrusted_index)
{
  if (untrusted_index < 500)
    return array[__builtin_speculation_safe_value (untrusted_index)];
  return 0;
}
```

The built-in function will either cause execution to stall until the conditional branch has been fully resolved, or it may permit speculative execution to continue, but using 0 instead of `untrusted_value` if that exceeds the limit.

If accessing any memory location is potentially unsafe when speculative execution is incorrect, then the code can be rewritten as

```
int array[500];
int f (unsigned untrusted_index)
{
  if (untrusted_index < 500)
    return *__builtin_speculation_safe_value (&array[untrusted_index], NULL);
  return 0;
}
```

which will cause a `NULL` pointer to be used for the unsafe case.

`int __builtin_types_compatible_p (`*`type1`*`, `*`type2`*`)` [Built-in Function]

You can use the built-in function `__builtin_types_compatible_p` to determine whether two types are the same.

This built-in function returns 1 if the unqualified versions of the types *type1* and *type2* (which are types, not expressions) are compatible, 0 otherwise. The result of this built-in function can be used in integer constant expressions.

This built-in function ignores top level qualifiers (e.g., `const`, `volatile`). For example, `int` is equivalent to `const int`.

The type `int[]` and `int[5]` are compatible. On the other hand, `int` and `char *` are not compatible, even if the size of their types, on the particular architecture are the same. Also, the amount of pointer indirection is taken into account when determining similarity. Consequently, `short *` is not similar to `short **`. Furthermore, two types that are typedefed are considered compatible if their underlying types are compatible.

An `enum` type is not considered to be compatible with another `enum` type even if both are compatible with the same integer type; this is what the C standard specifies. For example, `enum {foo, bar}` is not similar to `enum {hot, dog}`.

You typically use this function in code whose execution varies depending on the arguments' types. For example:

```
#define foo(x)                                                  \
  ({                                                           \
    typeof (x) tmp = (x);                                       \
    if (__builtin_types_compatible_p (typeof (x), long double)) \
      tmp = foo_long_double (tmp);                              \
    else if (__builtin_types_compatible_p (typeof (x), double)) \
      tmp = foo_double (tmp);                                   \
    else if (__builtin_types_compatible_p (typeof (x), float))  \
      tmp = foo_float (tmp);                                    \
    else                                                        \
      abort ();                                                 \
    tmp;                                                        \
  })
```

Note: This construct is only available for C.

`type`` __builtin_choose_expr (`*`const_exp`*`, `*`exp1`*`, `*`exp2`*`)` [Built-in Function]

You can use the built-in function `__builtin_choose_expr` to evaluate code depending on the value of a constant expression. This built-in function returns *exp1* if *const_exp*, which is an integer constant expression, is nonzero. Otherwise it returns *exp2*.

Like the '? :' operator, this built-in function does not evaluate the expression that is not chosen. For example, if *const_exp* evaluates to `true`, *exp2* is not evaluated even if it has side effects. On the other hand, `__builtin_choose_expr` differs from '? :' in that the first operand must be a compile-time constant, and the other operands are not subject to the '? :' type constraints and promotions.

This built-in function can return an lvalue if the chosen argument is an lvalue.

If *exp1* is returned, the return type is the same as *exp1*'s type. Similarly, if *exp2* is returned, its return type is the same as *exp2*.

Example:

```
#define foo(x)                                                  \
  __builtin_choose_expr (                                       \
    __builtin_types_compatible_p (typeof (x), double),          \
    foo_double (x),                                             \
    __builtin_choose_expr (                                     \
      __builtin_types_compatible_p (typeof (x), float),         \
      foo_float (x),                                            \
      /* The void expression results in a compile-time error  \
         when assigning the result to something.  */          \
      (void)0))
```

Note: This construct is only available for C. Furthermore, the unused expression (*exp1* or *exp2* depending on the value of *const_exp*) may still generate syntax errors. This may change in future revisions.

type `__builtin_tgmath` (*functions*, *arguments*) [Built-in Function]

The built-in function `__builtin_tgmath`, available only for C and Objective-C, calls a function determined according to the rules of `<tgmath.h>` macros. It is intended to be used in implementations of that header, so that expansions of macros from that header only expand each of their arguments once, to avoid problems when calls to such macros are nested inside the arguments of other calls to such macros; in addition, it results in better diagnostics for invalid calls to `<tgmath.h>` macros than implementations using other GNU C language features. For example, the `pow` type-generic macro might be defined as:

```
#define pow(a, b) __builtin_tgmath (powf, pow, powl, \
                                    cpowf, cpow, cpowl, a, b)
```

The arguments to `__builtin_tgmath` are at least two pointers to functions, followed by the arguments to the type-generic macro (which will be passed as arguments to the selected function). All the pointers to functions must be pointers to prototyped functions, none of which may have variable arguments, and all of which must have the same number of parameters; the number of parameters of the first function determines how many arguments to `__builtin_tgmath` are interpreted as function pointers, and how many as the arguments to the called function.

The types of the specified functions must all be different, but related to each other in the same way as a set of functions that may be selected between by a macro in `<tgmath.h>`. This means that the functions are parameterized by a floating-point type t, different for each such function. The function return types may all be the same type, or they may be t for each function, or they may be the real type corresponding to t for each function (if some of the types t are complex). Likewise, for each parameter position, the type of the parameter in that position may always be the same type, or may be *t* for each function (this case must apply for at least one parameter position), or may be the real type corresponding to *t* for each function.

The standard rules for `<tgmath.h>` macros are used to find a common type *u* from the types of the arguments for parameters whose types vary between the functions; complex integer types (a GNU extension) are treated like the complex type corresponding to the real floating type that would be chosen for the corresponding real integer type. If the function return types vary, or are all the same integer type, the function called is the one for which *t* is *u*, and it is an error if there is no such function. If the function return types are all the same floating-point type, the type-generic macro is taken to be one of those from TS 18661 that rounds the result to a narrower type; if there is a function for which *t* is *u*, it is called, and otherwise the first function, if any, for which *t* has at least the range and precision of *u* is called, and it is an error if there is no such function.

`int __builtin_constant_p (`*exp*`)` [Built-in Function]

You can use the built-in function `__builtin_constant_p` to determine if the expression *exp* is known to be constant at compile time and hence that GCC can perform constant-folding on expressions involving that value. The argument of the function is the expression to test. The expression is not evaluated, side-effects are discarded. The function returns the integer 1 if the argument is known to be a compile-time constant and 0 if it is not known to be a compile-time constant. Any expression that has side-effects makes the function return 0. A return of 0 does not indicate that the expression is *not* a constant, but merely that GCC cannot prove it is a constant within the constraints of the active set of optimization options.

You typically use this function in an embedded application where memory is a critical resource. If you have some complex calculation, you may want it to be folded if it involves constants, but need to call a function if it does not. For example:

```
#define Scale_Value(X)      \
  (__builtin_constant_p (X) \
  ? ((X) * SCALE + OFFSET) : Scale (X))
```

You may use this built-in function in either a macro or an inline function. However, if you use it in an inlined function and pass an argument of the function as the argument to the built-in, GCC never returns 1 when you call the inline function with a string constant or compound literal (see Section 6.2.10 [Compound Literals], page 614) and does not return 1 when you pass a constant numeric value to the inline function unless you specify the `-O` option.

You may also use `__builtin_constant_p` in initializers for static data. For instance, you can write

```
static const int table[] = {
   __builtin_constant_p (EXPRESSION) ? (EXPRESSION) : -1,
   /* ... */
};
```

This is an acceptable initializer even if *EXPRESSION* is not a constant expression, including the case where `__builtin_constant_p` returns 1 because *EXPRESSION* can be folded to a constant but *EXPRESSION* contains operands that are not otherwise permitted in a static initializer (for example, `0 && foo ()`). GCC must be more conservative about evaluating the built-in in this case, because it has no opportunity to perform optimization.

bool `__builtin_is_constant_evaluated (void)` [Built-in Function]

The `__builtin_is_constant_evaluated` function is available only in C++. The built-in is intended to be used by implementations of the `std::is_constant_evaluated` C++ function. Programs should make use of the latter function rather than invoking the built-in directly.

The main use case of the built-in is to determine whether a `constexpr` function is being called in a `constexpr` context. A call to the function evaluates to a core constant expression with the value `true` if and only if it occurs within the evaluation of an expression or conversion that is manifestly constant-evaluated as defined in the C++ standard. Manifestly constant-evaluated contexts include constant-expressions, the conditions of `constexpr if` statements, constraint-expressions, and initializers of variables usable in constant expressions. For more details refer to the latest revision of the C++ standard.

type `__builtin_counted_by_ref (`*ptr*`)` [Built-in Function]

The built-in function `__builtin_counted_by_ref` checks whether the array object pointed by the pointer *ptr* has another object associated with it that represents the number of elements in the array object through the `counted_by` attribute (i.e. the counted-by object). If so, returns a pointer to the corresponding counted-by object. If such counted-by object does not exist, returns a null pointer.

This built-in function is only available in C for now.

The argument *ptr* must be a pointer to an array. The *type* of the returned value is a pointer type pointing to the corresponding type of the counted-by object or a void pointer type in case of a null pointer being returned.

For example:

```
struct foo1 {
  int counter;
  struct bar1 array[] __attribute__((counted_by (counter)));
} *p;

struct foo2 {
  int other;
  struct bar2 array[];
} *q;
```

the following call to the built-in

```
__builtin_counted_by_ref (p->array)
```

returns:

```
&p->counter with type int *.
```

However, the following call to the built-in

```
__builtin_counted_by_ref (q->array)
```

returns a null pointer to `void`.

void `__builtin_clear_padding (`*ptr*`)` [Built-in Function]

The built-in function `__builtin_clear_padding` function clears padding bits inside of the object representation of object pointed by *ptr*, which has to be a pointer. The value representation of the object is not affected. The type of the object is assumed to be the type the pointer points to. Inside of a union, the only cleared bits are bits that are padding bits for all the union members.

This built-in-function is useful if the padding bits of an object might have indeterminate values and the object representation needs to be bitwise compared to some other object, for example for atomic operations.

For C++, *ptr* argument type should be pointer to trivially-copyable type, unless the argument is address of a variable or parameter, because otherwise it isn't known if the type isn't just a base class whose padding bits are reused or laid out differently in a derived class.

type `__builtin_bit_cast` (*type*, *arg*) [Built-in Function]

The `__builtin_bit_cast` function is available only in C++. The built-in is intended to be used by implementations of the `std::bit_cast` C++ template function. Programs should make use of the latter function rather than invoking the built-in directly.

This built-in function allows reinterpreting the bits of the *arg* argument as if it had type *type*. *type* and the type of the *arg* argument need to be trivially copyable types with the same size. When manifestly constant-evaluated, it performs extra diagnostics required for `std::bit_cast` and returns a constant expression if *arg* is a constant expression. For more details refer to the latest revision of the C++ standard.

`long __builtin_expect (long` *exp*`, long` *c*`)` [Built-in Function]

You may use `__builtin_expect` to provide the compiler with branch prediction information. In general, you should prefer to use actual profile feedback for this (`-fprofile-arcs`), as programmers are notoriously bad at predicting how their programs actually perform. However, there are applications in which this data is hard to collect.

The return value is the value of *exp*, which should be an integral expression. The semantics of the built-in are that it is expected that *exp* == *c*. For example:

```
if (__builtin_expect (x, 0))
  foo ();
```

indicates that we do not expect to call `foo`, since we expect `x` to be zero. Since you are limited to integral expressions for *exp*, you should use constructions such as

```
if (__builtin_expect (ptr != NULL, 1))
  foo (*ptr);
```

when testing pointer or floating-point values.

For the purposes of branch prediction optimizations, the probability that a `__builtin_expect` expression is `true` is controlled by GCC's `builtin-expect-probability` parameter, which defaults to 90%.

You can also use `__builtin_expect_with_probability` to explicitly assign a probability value to individual expressions. If the built-in is used in a loop construct, the provided probability will influence the expected number of iterations made by loop optimizations.

`long __builtin_expect_with_probability` [Built-in Function]

(long *exp*, long *c*, double *probability*)

This function has the same semantics as `__builtin_expect`, but the caller provides the expected probability that *exp* == *c*. The last argument, *probability*, is a floating-point value in the range 0.0 to 1.0, inclusive. The *probability* argument must be a constant floating-point expression.

`void __builtin_trap (void)` [Built-in Function]

This function causes the program to exit abnormally. GCC implements this function by using a target-dependent mechanism (such as intentionally executing an illegal instruction) or by calling `abort`. The mechanism used may vary from release to release so you should not rely on any particular implementation.

`void __builtin_unreachable (void)` [Built-in Function]

If control flow reaches the point of the `__builtin_unreachable`, the program is undefined. It is useful in situations where the compiler cannot deduce the unreachability of the code.

One such case is immediately following an `asm` statement that either never terminates, or one that transfers control elsewhere and never returns. In this example, without the `__builtin_unreachable`, GCC issues a warning that control reaches the end of a non-void function. It also generates code to return after the `asm`.

```
int f (int c, int v)
{
  if (c)
    {
      return v;
    }
  else
    {
      asm("jmp error_handler");
      __builtin_unreachable ();
    }
}
```

Because the `asm` statement unconditionally transfers control out of the function, control never reaches the end of the function body. The `__builtin_unreachable` is in fact unreachable and communicates this fact to the compiler.

Another use for `__builtin_unreachable` is following a call a function that never returns but that is not declared `__attribute__((noreturn))`, as in this example:

```
void function_that_never_returns (void);

int g (int c)
{
  if (c)
    {
      return 1;
    }
  else
    {
      function_that_never_returns ();
      __builtin_unreachable ();
    }
}
```

type __builtin_assoc_barrier (*type expr*) [Built-in Function]

This built-in inhibits re-association of the floating-point expression *expr* with expressions consuming the return value of the built-in. The expression *expr* itself can be reordered, and the whole expression *expr* can be reordered with operands after the barrier. The barrier is relevant when `-fassociative-math` is active.

```
float x0 = a + b - b;
float x1 = __builtin_assoc_barrier(a + b) - b;
```

means that, with `-fassociative-math`, `x0` can be optimized to `x0 = a` but `x1` cannot.

It is also relevant when `-ffp-contract=fast` is active; it will prevent contraction between expressions.

```
float x0 = a * b + c;
float x1 = __builtin_assoc_barrier (a * b) + c;
```

means that, with `-ffp-contract=fast`, `x0` may be optimized to use a fused multiply-add instruction but `x1` cannot.

void * __builtin_assume_aligned (const void **exp*, size_t *align*, ...) [Built-in Function]

This function returns its first argument, and allows the compiler to assume that the returned pointer is at least *align* bytes aligned. This built-in can have either two or three arguments, if it has three, the third argument should have integer type, and if it is nonzero means misalignment offset. For example:

```
void *x = __builtin_assume_aligned (arg, 16);
```

means that the compiler can assume `x`, set to `arg`, is at least 16-byte aligned, while:

```
void *x = __builtin_assume_aligned (arg, 32, 8);
```

means that the compiler can assume for `x`, set to `arg`, that `(char *) x - 8` is 32-byte aligned.

int __builtin_LINE () [Built-in Function]

This function is the equivalent of the preprocessor `__LINE__` macro and returns a constant integer expression that evaluates to the line number of the invocation of the built-in. When used as a C++ default argument for a function *F*, it returns the line number of the call to *F*.

const char * __builtin_FUNCTION () [Built-in Function]

This function is the equivalent of the `__FUNCTION__` symbol and returns an address constant pointing to the name of the function from which the built-in was invoked, or the empty string if the invocation is not at function scope. When used as a C++ default argument for a function *F*, it returns the name of *F*'s caller or the empty string if the call was not made at function scope.

const char * __builtin_FILE () [Built-in Function]

This function is the equivalent of the preprocessor `__FILE__` macro and returns an address constant pointing to the file name containing the invocation of the built-in, or the empty string if the invocation is not at function scope. When used as a C++ default argument for a function *F*, it returns the file name of the call to *F* or the empty string if the call was not made at function scope.

For example, in the following, each call to function `foo` will print a line similar to `"file.c:123: foo: message"` with the name of the file and the line number of the `printf` call, the name of the function `foo`, followed by the word `message`.

```
const char*
function (const char *func = __builtin_FUNCTION ())
{
  return func;
}

void foo (void)
{
  printf ("%s:%i: %s: message\n", file (), line (), function ());
}
```

`void __builtin___clear_cache (void *begin, void *end)` [Built-in Function]

This function is used to flush the processor's instruction cache for the region of memory between *begin* inclusive and *end* exclusive. Some targets require that the instruction cache be flushed, after modifying memory containing code, in order to obtain deterministic behavior.

If the target does not require instruction cache flushes, `__builtin___clear_cache` has no effect. Otherwise either instructions are emitted in-line to clear the instruction cache or a call to the `__clear_cache` function in libgcc is made.

`void __builtin_prefetch (const void *addr, ...)` [Built-in Function]

This function is used to minimize cache-miss latency by moving data into a cache before it is accessed. You can insert calls to `__builtin_prefetch` into code for which you know addresses of data in memory that is likely to be accessed soon. If the target supports them, data prefetch instructions are generated. If the prefetch is done early enough before the access then the data will be in the cache by the time it is accessed.

The value of *addr* is the address of the memory to prefetch. There are two optional arguments, *rw* and *locality*. The value of *rw* is a compile-time constant zero, one or two; one means that the prefetch is preparing for a write to the memory address, two means that the prefetch is preparing for a shared read (expected to be read by at least one other processor before it is written if written at all) and zero, the default, means that the prefetch is preparing for a read. The value *locality* must be a compile-time constant integer between zero and three. A value of zero means that the data has no temporal locality, so it need not be left in the cache after the access. A value of three means that the data has a high degree of temporal locality and should be left in all levels of cache possible. Values of one and two mean, respectively, a low or moderate degree of temporal locality. The default is three.

```
for (i = 0; i < n; i++)
  {
    a[i] = a[i] + b[i];
    __builtin_prefetch (&a[i+j], 1, 1);
    __builtin_prefetch (&b[i+j], 0, 1);
    /* ... */
  }
```

Data prefetch does not generate faults if *addr* is invalid, but the address expression itself must be valid. For example, a prefetch of `p->next` does not fault if `p->next` is not a valid address, but evaluation faults if `p` is not a valid address.

If the target does not support data prefetch, the address expression is evaluated if it includes side effects but no other code is generated and GCC does not issue a warning.

`int __builtin_classify_type (`*arg*`)` [Built-in Function]
`int __builtin_classify_type (`*type*`)` [Built-in Function]

The `__builtin_classify_type` returns a small integer with a category of *arg* argument's type, like void type, integer type, enumeral type, boolean type, pointer type, reference type, offset type, real type, complex type, function type, method type, record type, union type, array type, string type, bit-precise integer type, vector type, etc. When the argument is an expression, for backwards compatibility reason the argument is promoted like arguments passed to `...` in varargs function, so some classes are never returned in certain languages. Alternatively, the argument of the built-in function can be a typename, such as the `typeof` specifier.

```
int a[2];
__builtin_classify_type (a) == __builtin_classify_type (int[5]);
__builtin_classify_type (a) == __builtin_classify_type (void*);
__builtin_classify_type (typeof (a)) == __builtin_classify_type (int[5]);
```

The first comparison will never be true, as *a* is implicitly converted to pointer. The last two comparisons will be true as they classify pointers in the second case and arrays in the last case.

`Pmode __builtin_extend_pointer (void *` *x*`)` [Built-in Function]

On targets where the user visible pointer size is smaller than the size of an actual hardware address this function returns the extended user pointer. Targets where this is true included ILP32 mode on x86_64 or Aarch64. This function is mainly useful when writing inline assembly code.

`int __builtin_goacc_parlevel_id (int` *x*`)` [Built-in Function]

Returns the openacc gang, worker or vector id depending on whether *x* is 0, 1 or 2.

`int __builtin_goacc_parlevel_size (int` *x*`)` [Built-in Function]

Returns the openacc gang, worker or vector size depending on whether *x* is 0, 1 or 2.

7.13 Built-in Functions Specific to Particular Target Machines

On some target machines, GCC supports many built-in functions specific to those machines. Generally these generate calls to specific machine instructions, but allow the compiler to schedule those calls.

7.13.1 AArch64 Built-in Functions

These built-in functions are available for the AArch64 family of processors.

```
unsigned int __builtin_aarch64_get_fpcr ();
void __builtin_aarch64_set_fpcr (unsigned int);
unsigned int __builtin_aarch64_get_fpsr ();
void __builtin_aarch64_set_fpsr (unsigned int);
```

```
unsigned long long __builtin_aarch64_get_fpcr64 ();
void __builtin_aarch64_set_fpcr64 (unsigned long long);
unsigned long long __builtin_aarch64_get_fpsr64 ();
void __builtin_aarch64_set_fpsr64 (unsigned long long);
```

7.13.2 Alpha Built-in Functions

These built-in functions are available for the Alpha family of processors, depending on the command-line switches used.

The following built-in functions are always available. They all generate the machine instruction that is part of the name.

```
long __builtin_alpha_implver (void);
long __builtin_alpha_rpcc (void);
long __builtin_alpha_amask (long);
long __builtin_alpha_cmpbge (long, long);
long __builtin_alpha_extbl (long, long);
long __builtin_alpha_extwl (long, long);
long __builtin_alpha_extll (long, long);
long __builtin_alpha_extql (long, long);
long __builtin_alpha_extwh (long, long);
long __builtin_alpha_extlh (long, long);
long __builtin_alpha_extqh (long, long);
long __builtin_alpha_insbl (long, long);
long __builtin_alpha_inswl (long, long);
long __builtin_alpha_insll (long, long);
long __builtin_alpha_insql (long, long);
long __builtin_alpha_inswh (long, long);
long __builtin_alpha_inslh (long, long);
long __builtin_alpha_insqh (long, long);
long __builtin_alpha_mskbl (long, long);
long __builtin_alpha_mskwl (long, long);
long __builtin_alpha_mskll (long, long);
long __builtin_alpha_mskql (long, long);
long __builtin_alpha_mskwh (long, long);
long __builtin_alpha_msklh (long, long);
long __builtin_alpha_mskqh (long, long);
long __builtin_alpha_umulh (long, long);
long __builtin_alpha_zap (long, long);
long __builtin_alpha_zapnot (long, long);
```

The following built-in functions are always with `-mmax` or `-mcpu=`*cpu* where *cpu* is `pca56` or later. They all generate the machine instruction that is part of the name.

```
long __builtin_alpha_pklb (long);
long __builtin_alpha_pkwb (long);
long __builtin_alpha_unpkbl (long);
long __builtin_alpha_unpkbw (long);
long __builtin_alpha_minub8 (long, long);
long __builtin_alpha_minsb8 (long, long);
long __builtin_alpha_minuw4 (long, long);
long __builtin_alpha_minsw4 (long, long);
long __builtin_alpha_maxub8 (long, long);
long __builtin_alpha_maxsb8 (long, long);
long __builtin_alpha_maxuw4 (long, long);
long __builtin_alpha_maxsw4 (long, long);
long __builtin_alpha_perr (long, long);
```

The following built-in functions are always with `-mcix` or `-mcpu=cpu` where *cpu* is `ev67` or later. They all generate the machine instruction that is part of the name.

```
long __builtin_alpha_cttz (long);
long __builtin_alpha_ctlz (long);
long __builtin_alpha_ctpop (long);
```

The following built-in functions are available on systems that use the OSF/1 PALcode. Normally they invoke the `rduniq` and `wruniq` PAL calls, but when invoked with `-mtls-kernel`, they invoke `rdval` and `wrval`.

```
void *__builtin_thread_pointer (void);
void __builtin_set_thread_pointer (void *);
```

7.13.3 ARC Built-in Functions

The following built-in functions are provided for ARC targets. The built-ins generate the corresponding assembly instructions. In the examples given below, the generated code often requires an operand or result to be in a register. Where necessary further code will be generated to ensure this is true, but for brevity this is not described in each case.

Note: Using a built-in to generate an instruction not supported by a target may cause problems. At present the compiler is not guaranteed to detect such misuse, and as a result an internal compiler error may be generated.

`int __builtin_arc_aligned (void *val, int alignval)` [Built-in Function]

Return 1 if *val* is known to have the byte alignment given by *alignval*, otherwise return 0. Note that this is different from

```
__alignof__(*(char *)val) >= alignval
```

because __alignof__ sees only the type of the dereference, whereas __builtin_arc_align uses alignment information from the pointer as well as from the pointed-to type. The information available will depend on optimization level.

`void __builtin_arc_brk (void)` [Built-in Function]

Generates

```
brk
```

`unsigned int __builtin_arc_core_read (unsigned int regno)` [Built-in Function]

The operand is the number of a register to be read. Generates:

```
mov  dest, rregno
```

where the value in *dest* will be the result returned from the built-in.

`void __builtin_arc_core_write (unsigned int regno, unsigned int val)` [Built-in Function]

The first operand is the number of a register to be written, the second operand is a compile time constant to write into that register. Generates:

```
mov  rregno, val
```

`int __builtin_arc_divaw (int a, int b)` [Built-in Function]

Only available if either `-mcpu=ARC700` or `-meA` is set. Generates:

```
divaw  dest, a, b
```

where the value in *dest* will be the result returned from the built-in.

void __builtin_arc_flag (unsigned int *a*) [Built-in Function]

Generates

```
flag  a
```

unsigned int __builtin_arc_lr (unsigned int *auxr*) [Built-in Function]

The operand, *auxv*, is the address of an auxiliary register and must be a compile time constant. Generates:

```
lr  dest, [auxr]
```

Where the value in *dest* will be the result returned from the built-in.

void __builtin_arc_mul64 (int *a*, int *b*) [Built-in Function]

Only available with -mmul64. Generates:

```
mul64  a, b
```

void __builtin_arc_mulu64 (unsigned int *a*, unsigned int *b*) [Built-in Function]

Only available with -mmul64. Generates:

```
mulu64  a, b
```

void __builtin_arc_nop (void) [Built-in Function]

Generates:

```
nop
```

int __builtin_arc_norm (int *src*) [Built-in Function]

Only valid if the 'norm' instruction is available through the -mnorm option or by default with -mcpu=ARC700. Generates:

```
norm  dest, src
```

Where the value in *dest* will be the result returned from the built-in.

short int __builtin_arc_normw (short int *src*) [Built-in Function]

Only valid if the 'normw' instruction is available through the -mnorm option or by default with -mcpu=ARC700. Generates:

```
normw  dest, src
```

Where the value in *dest* will be the result returned from the built-in.

void __builtin_arc_rtie (void) [Built-in Function]

Generates:

```
rtie
```

void __builtin_arc_sleep (int *a* [Built-in Function]

Generates:

```
sleep  a
```

void __builtin_arc_sr (unsigned int *val*, unsigned int *auxr*) [Built-in Function]

The first argument, *val*, is a compile time constant to be written to the register, the second argument, *auxr*, is the address of an auxiliary register. Generates:

```
sr  val, [auxr]
```

`int __builtin_arc_swap (int src)` [Built-in Function]

Only valid with `-mswap`. Generates:

```
swap  dest, src
```

Where the value in *dest* will be the result returned from the built-in.

`void __builtin_arc_swi (void)` [Built-in Function]

Generates:

```
swi
```

`void __builtin_arc_sync (void)` [Built-in Function]

Only available with `-mcpu=ARC700`. Generates:

```
sync
```

`void __builtin_arc_trap_s (unsigned int c)` [Built-in Function]

Only available with `-mcpu=ARC700`. Generates:

```
trap_s  c
```

`void __builtin_arc_unimp_s (void)` [Built-in Function]

Only available with `-mcpu=ARC700`. Generates:

```
unimp_s
```

The instructions generated by the following builtins are not considered as candidates for scheduling. They are not moved around by the compiler during scheduling, and thus can be expected to appear where they are put in the C code:

```
__builtin_arc_brk()
__builtin_arc_core_read()
__builtin_arc_core_write()
__builtin_arc_flag()
__builtin_arc_lr()
__builtin_arc_sleep()
__builtin_arc_sr()
__builtin_arc_swi()
```

The following built-in functions are available for the ARCv2 family of processors.

```
int __builtin_arc_clri ();
void __builtin_arc_kflag (unsigned);
void __builtin_arc_seti (int);
```

The following built-in functions are available for the ARCv2 family and uses `-mnorm`.

```
int __builtin_arc_ffs (int);
int __builtin_arc_fls (int);
```

7.13.4 ARC SIMD Built-in Functions

SIMD builtins provided by the compiler can be used to generate the vector instructions. This section describes the available builtins and their usage in programs. With the `-msimd` option, the compiler provides 128-bit vector types, which can be specified using the `vector_size` attribute. The header file `arc-simd.h` can be included to use the following predefined types:

```
typedef int __v4si   __attribute__((vector_size(16)));
```

```
typedef short __v8hi __attribute__((vector_size(16)));
```

These types can be used to define 128-bit variables. The built-in functions listed in the following section can be used on these variables to generate the vector operations.

For all builtins, `__builtin_arc_someinsn`, the header file `arc-simd.h` also provides equivalent macros called `_someinsn` that can be used for programming ease and improved readability. The following macros for DMA control are also provided:

```
#define _setup_dma_in_channel_reg _vdiwr
#define _setup_dma_out_channel_reg _vdowr
```

The following is a complete list of all the SIMD built-ins provided for ARC, grouped by calling signature.

The following take two `__v8hi` arguments and return a `__v8hi` result:

```
__v8hi __builtin_arc_vaddaw (__v8hi, __v8hi);
__v8hi __builtin_arc_vaddw (__v8hi, __v8hi);
__v8hi __builtin_arc_vand (__v8hi, __v8hi);
__v8hi __builtin_arc_vandaw (__v8hi, __v8hi);
__v8hi __builtin_arc_vavb (__v8hi, __v8hi);
__v8hi __builtin_arc_vavrb (__v8hi, __v8hi);
__v8hi __builtin_arc_vbic (__v8hi, __v8hi);
__v8hi __builtin_arc_vbicaw (__v8hi, __v8hi);
__v8hi __builtin_arc_vdifaw (__v8hi, __v8hi);
__v8hi __builtin_arc_vdifw (__v8hi, __v8hi);
__v8hi __builtin_arc_veqw (__v8hi, __v8hi);
__v8hi __builtin_arc_vh264f (__v8hi, __v8hi);
__v8hi __builtin_arc_vh264ft (__v8hi, __v8hi);
__v8hi __builtin_arc_vh264fw (__v8hi, __v8hi);
__v8hi __builtin_arc_vlew (__v8hi, __v8hi);
__v8hi __builtin_arc_vltw (__v8hi, __v8hi);
__v8hi __builtin_arc_vmaxaw (__v8hi, __v8hi);
__v8hi __builtin_arc_vmaxw (__v8hi, __v8hi);
__v8hi __builtin_arc_vminaw (__v8hi, __v8hi);
__v8hi __builtin_arc_vminw (__v8hi, __v8hi);
__v8hi __builtin_arc_vmr1aw (__v8hi, __v8hi);
__v8hi __builtin_arc_vmr1w (__v8hi, __v8hi);
__v8hi __builtin_arc_vmr2aw (__v8hi, __v8hi);
__v8hi __builtin_arc_vmr2w (__v8hi, __v8hi);
__v8hi __builtin_arc_vmr3aw (__v8hi, __v8hi);
__v8hi __builtin_arc_vmr3w (__v8hi, __v8hi);
__v8hi __builtin_arc_vmr4aw (__v8hi, __v8hi);
__v8hi __builtin_arc_vmr4w (__v8hi, __v8hi);
__v8hi __builtin_arc_vmr5aw (__v8hi, __v8hi);
__v8hi __builtin_arc_vmr5w (__v8hi, __v8hi);
__v8hi __builtin_arc_vmr6aw (__v8hi, __v8hi);
__v8hi __builtin_arc_vmr6w (__v8hi, __v8hi);
__v8hi __builtin_arc_vmr7aw (__v8hi, __v8hi);
__v8hi __builtin_arc_vmr7w (__v8hi, __v8hi);
```

```
__v8hi __builtin_arc_vmrb (__v8hi, __v8hi);
__v8hi __builtin_arc_vmulaw (__v8hi, __v8hi);
__v8hi __builtin_arc_vmulfaw (__v8hi, __v8hi);
__v8hi __builtin_arc_vmulfw (__v8hi, __v8hi);
__v8hi __builtin_arc_vmulw (__v8hi, __v8hi);
__v8hi __builtin_arc_vnew (__v8hi, __v8hi);
__v8hi __builtin_arc_vor (__v8hi, __v8hi);
__v8hi __builtin_arc_vsubaw (__v8hi, __v8hi);
__v8hi __builtin_arc_vsubw (__v8hi, __v8hi);
__v8hi __builtin_arc_vsummw (__v8hi, __v8hi);
__v8hi __builtin_arc_vvc1f (__v8hi, __v8hi);
__v8hi __builtin_arc_vvc1ft (__v8hi, __v8hi);
__v8hi __builtin_arc_vxor (__v8hi, __v8hi);
__v8hi __builtin_arc_vxoraw (__v8hi, __v8hi);
```

The following take one `__v8hi` and one `int` argument and return a `__v8hi` result:

```
__v8hi __builtin_arc_vbaddw (__v8hi, int);
__v8hi __builtin_arc_vbmaxw (__v8hi, int);
__v8hi __builtin_arc_vbminw (__v8hi, int);
__v8hi __builtin_arc_vbmulaw (__v8hi, int);
__v8hi __builtin_arc_vbmulfw (__v8hi, int);
__v8hi __builtin_arc_vbmulw (__v8hi, int);
__v8hi __builtin_arc_vbrsubw (__v8hi, int);
__v8hi __builtin_arc_vbsubw (__v8hi, int);
```

The following take one `__v8hi` argument and one `int` argument which must be a 3-bit compile time constant indicating a register number I0-I7. They return a `__v8hi` result.

```
__v8hi __builtin_arc_vasrw (__v8hi, const int);
__v8hi __builtin_arc_vsr8 (__v8hi, const int);
__v8hi __builtin_arc_vsr8aw (__v8hi, const int);
```

The following take one `__v8hi` argument and one `int` argument which must be a 6-bit compile time constant. They return a `__v8hi` result.

```
__v8hi __builtin_arc_vasrpwbi (__v8hi, const int);
__v8hi __builtin_arc_vasrrpwbi (__v8hi, const int);
__v8hi __builtin_arc_vasrrwi (__v8hi, const int);
__v8hi __builtin_arc_vasrsrwi (__v8hi, const int);
__v8hi __builtin_arc_vasrwi (__v8hi, const int);
__v8hi __builtin_arc_vsr8awi (__v8hi, const int);
__v8hi __builtin_arc_vsr8i (__v8hi, const int);
```

The following take one `__v8hi` argument and one `int` argument which must be a 8-bit compile time constant. They return a `__v8hi` result.

```
__v8hi __builtin_arc_vd6tapf (__v8hi, const int);
__v8hi __builtin_arc_vmvaw (__v8hi, const int);
__v8hi __builtin_arc_vmvw (__v8hi, const int);
__v8hi __builtin_arc_vmvzw (__v8hi, const int);
```

The following take two `int` arguments, the second of which which must be a 8-bit compile time constant. They return a `__v8hi` result:

```
__v8hi __builtin_arc_vmovaw (int, const int);
__v8hi __builtin_arc_vmovw (int, const int);
__v8hi __builtin_arc_vmovzw (int, const int);
```

The following take a single `__v8hi` argument and return a `__v8hi` result:

```
__v8hi __builtin_arc_vabsaw (__v8hi);
__v8hi __builtin_arc_vabsw (__v8hi);
__v8hi __builtin_arc_vaddsuw (__v8hi);
__v8hi __builtin_arc_vexch1 (__v8hi);
__v8hi __builtin_arc_vexch2 (__v8hi);
__v8hi __builtin_arc_vexch4 (__v8hi);
__v8hi __builtin_arc_vsignw (__v8hi);
__v8hi __builtin_arc_vupbaw (__v8hi);
__v8hi __builtin_arc_vupbw (__v8hi);
__v8hi __builtin_arc_vupsbaw (__v8hi);
__v8hi __builtin_arc_vupsbw (__v8hi);
```

The following take two `int` arguments and return no result:

```
void __builtin_arc_vdirun (int, int);
void __builtin_arc_vdorun (int, int);
```

The following take two `int` arguments and return no result. The first argument must a 3-bit compile time constant indicating one of the DR0-DR7 DMA setup channels:

```
void __builtin_arc_vdiwr (const int, int);
void __builtin_arc_vdowr (const int, int);
```

The following take an `int` argument and return no result:

```
void __builtin_arc_vendrec (int);
void __builtin_arc_vrec (int);
void __builtin_arc_vrecrun (int);
void __builtin_arc_vrun (int);
```

The following take a `__v8hi` argument and two `int` arguments and return a `__v8hi` result. The second argument must be a 3-bit compile time constants, indicating one the registers I0-I7, and the third argument must be an 8-bit compile time constant.

Note: Although the equivalent hardware instructions do not take an SIMD register as an operand, these builtins overwrite the relevant bits of the `__v8hi` register provided as the first argument with the value loaded from the `[Ib, u8]` location in the SDM.

```
__v8hi __builtin_arc_vld32 (__v8hi, const int, const int);
__v8hi __builtin_arc_vld32wh (__v8hi, const int, const int);
__v8hi __builtin_arc_vld32wl (__v8hi, const int, const int);
__v8hi __builtin_arc_vld64 (__v8hi, const int, const int);
```

The following take two `int` arguments and return a `__v8hi` result. The first argument must be a 3-bit compile time constants, indicating one the registers I0-I7, and the second argument must be an 8-bit compile time constant.

```
__v8hi __builtin_arc_vld128 (const int, const int);
__v8hi __builtin_arc_vld64w (const int, const int);
```

The following take a `__v8hi` argument and two `int` arguments and return no result. The second argument must be a 3-bit compile time constants, indicating one the registers I0-I7, and the third argument must be an 8-bit compile time constant.

```
void __builtin_arc_vst128 (__v8hi, const int, const int);
void __builtin_arc_vst64 (__v8hi, const int, const int);
```

The following take a `__v8hi` argument and three `int` arguments and return no result. The second argument must be a 3-bit compile-time constant, identifying the 16-bit sub-register to be stored, the third argument must be a 3-bit compile time constants, indicating one the registers I0-I7, and the fourth argument must be an 8-bit compile time constant.

```
void __builtin_arc_vst16_n (__v8hi, const int, const int, const int);
void __builtin_arc_vst32_n (__v8hi, const int, const int, const int);
```

The following built-in functions are available on systems that uses `-mmpy-option=6` or higher.

```
__v2hi __builtin_arc_dmach (__v2hi, __v2hi);
__v2hi __builtin_arc_dmachu (__v2hi, __v2hi);
__v2hi __builtin_arc_dmpyh (__v2hi, __v2hi);
__v2hi __builtin_arc_dmpyhu (__v2hi, __v2hi);
__v2hi __builtin_arc_vaddsub2h (__v2hi, __v2hi);
__v2hi __builtin_arc_vsubadd2h (__v2hi, __v2hi);
```

The following built-in functions are available on systems that uses `-mmpy-option=7` or higher.

```
__v2si __builtin_arc_vmac2h (__v2hi, __v2hi);
__v2si __builtin_arc_vmac2hu (__v2hi, __v2hi);
__v2si __builtin_arc_vmpy2h (__v2hi, __v2hi);
__v2si __builtin_arc_vmpy2hu (__v2hi, __v2hi);
```

The following built-in functions are available on systems that uses `-mmpy-option=8` or higher.

```
long long __builtin_arc_qmach (__v4hi, __v4hi);
long long __builtin_arc_qmachu (__v4hi, __v4hi);
long long __builtin_arc_qmpyh (__v4hi, __v4hi);
long long __builtin_arc_qmpyhu (__v4hi, __v4hi);
long long __builtin_arc_dmacwh (__v2si, __v2hi);
long long __builtin_arc_dmacwhu (__v2si, __v2hi);
_v2si __builtin_arc_vaddsub (__v2si, __v2si);
_v2si __builtin_arc_vsubadd (__v2si, __v2si);
_v4hi __builtin_arc_vaddsub4h (__v4hi, __v4hi);
_v4hi __builtin_arc_vsubadd4h (__v4hi, __v4hi);
```

7.13.5 Arm C Language Extensions (ACLE)

GCC implements extensions for C and C++ as described in the Arm C Language Extensions (ACLE) specification, which can be found at `https://arm-software.github.io/acle/main/`.

As a part of ACLE, GCC implements extensions for Arm Vector extensions as described in the Arm C Language Extensions Specification. The complete list of Arm Vector extension intrinsics is available at https://arm-software.github.io/acle/main/. The built-in intrinsics for the Arm vector extensions are available when the respective extensions are enabled.

Not all aspects of ACLE are supported. Support for each feature of the ACLE is determined with the `__ARM_FEATURE_X` macros.

See Section 3.20.5 [ARM Options], page 371, and Section 3.20.1 [AArch64 Options], page 345, for more information on the availability of extensions.

7.13.6 ARM Floating Point Status and Control Intrinsics

These built-in functions are available for the ARM family of processors with floating-point unit.

```
unsigned int __builtin_arm_get_fpscr ();
void __builtin_arm_set_fpscr (unsigned int);
```

7.13.7 ARM ARMv8-M Security Extensions

GCC implements the ARMv8-M Security Extensions as described in the ARMv8-M Security Extensions: Requirements on Development Tools Engineering Specification, which can be found at https://developer.arm.com/documentation/ecm0359818/latest/.

As part of the Security Extensions GCC implements two new function attributes: `cmse_nonsecure_entry` and `cmse_nonsecure_call`.

As part of the Security Extensions GCC implements the intrinsics below. FPTR is used here to mean any function pointer type.

```
cmse_address_info_t cmse_TT (void *);
cmse_address_info_t cmse_TT_fptr (FPTR);
cmse_address_info_t cmse_TTT (void *);
cmse_address_info_t cmse_TTT_fptr (FPTR);
cmse_address_info_t cmse_TTA (void *);
cmse_address_info_t cmse_TTA_fptr (FPTR);
cmse_address_info_t cmse_TTAT (void *);
cmse_address_info_t cmse_TTAT_fptr (FPTR);
void * cmse_check_address_range (void *, size_t, int);
typeof(p) cmse_nsfptr_create (FPTR p);
intptr_t cmse_is_nsfptr (FPTR);
int cmse_nonsecure_caller (void);
```

7.13.8 AVR Built-in Functions

For each built-in function for AVR, there is an equally named, uppercase built-in macro defined. That way users can easily query if or if not a specific built-in is implemented or not. For example, if `__builtin_avr_nop` is available the macro `__BUILTIN_AVR_NOP` is defined to `1` and undefined otherwise.

`void __builtin_avr_nop (void)` [Built-in Function]
`void __builtin_avr_sei (void)` [Built-in Function]
`void __builtin_avr_cli (void)` [Built-in Function]
`void __builtin_avr_sleep (void)` [Built-in Function]
`void __builtin_avr_wdr (void)` [Built-in Function]
`uint8_t __builtin_avr_swap (uint8_t)` [Built-in Function]
`uint16_t __builtin_avr_fmul (uint8_t, uint8_t)` [Built-in Function]

int16_t __builtin_avr_fmuls (int8_t, int8_t) [Built-in Function]
int16_t __builtin_avr_fmulsu (int8_t, uint8_t) [Built-in Function]

These built-in functions map to the respective machine instruction, i.e. `nop`, `sei`, `cli`, `sleep`, `wdr`, `swap`, `fmul`, `fmuls` resp. `fmulsu`. The three `fmul*` built-ins are implemented as library call if no hardware multiplier is available.

void __builtin_avr_delay_cycles (uint32_t *ticks*) [Built-in Function]

Delay execution for *ticks* cycles. Note that this built-in does not take into account the effect of interrupts that might increase delay time. *ticks* must be a compile-time integer constant; delays with a variable number of cycles are not supported.

uint8_t __builtin_avr_insert_bits (uint32_t *map*, uint8_t *bits*, uint8_t *val*) [Built-in Function]

Insert bits from *bits* into *val* and return the resulting value. The nibbles of *map* determine how the insertion is performed: Let X be the n-th nibble of *map*

1. If X is `0xf`, then the n-th bit of *val* is returned unaltered.
2. If X is in the range 0...7, then the n-th result bit is set to the X-th bit of *bits*
3. If X is in the range 8...`0xe`, then the n-th result bit is undefined.

One typical use case for this built-in is adjusting input and output values to non-contiguous port layouts. Some examples:

```
// same as val, bits is unused
__builtin_avr_insert_bits (0xffffffff, bits, val);
// same as bits, val is unused
__builtin_avr_insert_bits (0x76543210, bits, val);
// same as rotating bits by 4
__builtin_avr_insert_bits (0x32107654, bits, 0);
// high nibble of result is the high nibble of val
// low nibble of result is the low nibble of bits
__builtin_avr_insert_bits (0xffff3210, bits, val);
// reverse the bit order of bits
__builtin_avr_insert_bits (0x01234567, bits, 0);
```

uint8_t __builtin_avr_mask1 (uint8_t *mask*, uint8_t *offs*) [Built-in Function]

Rotate the 8-bit constant value *mask* by an offset of *offs*, where *mask* is in { 0x01, 0xfe, 0x7f, 0x80 }. This built-in can be used as an alternative to 8-bit expressions like `1 << offs` when their computation consumes too much time, and *offs* is known to be in the range 0...7.

```
__builtin_avr_mask1 (1, offs)      // same like  1 << offs
__builtin_avr_mask1 (~1, offs)     // same like  ~(1 << offs)
__builtin_avr_mask1 (0x80, offs)   // same like  0x80 >> offs
__builtin_avr_mask1 (~0x80, offs)  // same like  ~(0x80 >> offs)
```

The open coded C versions take at least `5 + 4 * offs` cycles (and 5 instructions), whereas the built-in takes 7 cycles and instructions (8 cycles and instructions in the case of `mask = 0x7f`).

void __builtin_avr_nops (uint16_t *count*) [Built-in Function]

Insert *count* `NOP` instructions. The number of instructions must be a compile-time integer constant.

All of the following built-in functions are only available for GNU-C

`int8_t __builtin_avr_flash_segment (const __memx void*)` [Built-in Function]

This built-in takes a byte address to the 24-bit [AVR Named Address Spaces], page 617, `__memx` and returns the number of the flash segment (the 64 KiB chunk) where the address points to. Counting starts at `0`. If the address does not point to flash memory, return `-1`.

`size_t __builtin_avr_strlen_flash (const __flash char*)` [Built-in Function]
`size_t __builtin_avr_strlen_flashx (const __flashx char*)` [Built-in Function]
`size_t __builtin_avr_strlen_memx (const __memx char*)` [Built-in Function]

These built-ins return the length of a string located in named address-space `__flash`, `__flashx` or `__memx`, respectively. They are used to support functions like `strlen_F` from AVR-LibC (`https://avrdudes.github.io/avr-libc/avr-libc-user-manual/`)'s header `avr/flash.h`.

There are many more AVR-specific built-in functions that are used to implement the ISO/IEC TR 18037 "Embedded C" fixed-point functions of section 7.18a.6. You don't need to use these built-ins directly. Instead, use the declarations as supplied by the `stdfix.h` header with GNU-C99:

```
#include <stdfix.h>

// Re-interpret the bit representation of unsigned 16-bit
// integer uval as Q-format 0.16 value.
unsigned fract get_bits (uint_ur_t uval)
{
    return urbits (uval);
}
```

7.13.9 Blackfin Built-in Functions

Currently, there are two Blackfin-specific built-in functions. These are used for generating `CSYNC` and `SSYNC` machine insns without using inline assembly; by using these built-in functions the compiler can automatically add workarounds for hardware errata involving these instructions. These functions are named as follows:

```
void __builtin_bfin_csync (void);
void __builtin_bfin_ssync (void);
```

7.13.10 BPF Built-in Functions

The following built-in functions are available for eBPF targets.

`unsigned long long __builtin_bpf_load_byte (unsigned long long` *`offset`*`)` [Built-in Function]

Load a byte from the `struct sk_buff` packet data pointed to by the register `%r6`, and return it.

`unsigned long long __builtin_bpf_load_half (unsigned long long offset)` [Built-in Function]

Load 16 bits from the `struct sk_buff` packet data pointed to by the register `%r6`, and return it.

`unsigned long long __builtin_bpf_load_word (unsigned long long offset)` [Built-in Function]

Load 32 bits from the `struct sk_buff` packet data pointed to by the register `%r6`, and return it.

`type __builtin_preserve_access_index (type expr)` [Built-in Function]

BPF Compile Once-Run Everywhere (CO-RE) support. Instruct GCC to generate CO-RE relocation records for any accesses to aggregate data structures (struct, union, array types) in *expr*. This builtin is otherwise transparent; *expr* may have any type and its value is returned. This builtin has no effect if `-mco-re` is not in effect (either specified or implied).

`unsigned int __builtin_preserve_field_info (expr, unsigned int kind)` [Built-in Function]

BPF Compile Once-Run Everywhere (CO-RE) support. This builtin is used to extract information to aid in struct/union relocations. *expr* is an access to a field of a struct or union. Depending on *kind*, different information is returned to the program. A CO-RE relocation for the access in *expr* with kind *kind* is recorded if `-mco-re` is in effect.

The following values are supported for *kind*:

`FIELD_BYTE_OFFSET = 0`
: The returned value is the offset, in bytes, of the field from the beginning of the containing structure. For bit-fields, this is the byte offset of the containing word.

`FIELD_BYTE_SIZE = 1`
: The returned value is the size, in bytes, of the field. For bit-fields, this is the size in bytes of the containing word.

`FIELD_EXISTENCE = 2`
: The returned value is 1 if the field exists, 0 otherwise. Always 1 at compile time.

`FIELD_SIGNEDNESS = 3`
: The returned value is 1 if the field is signed, 0 otherwise.

`FIELD_LSHIFT_U64 = 4`
`FIELD_RSHIFT_U64 = 5`
: The returned value is the number of bits of left- or right-shifting (respectively) needed in order to recover the original value of the field, after it has been loaded by a read of `FIELD_BYTE_SIZE` bytes into an unsigned 64-bit value. Primarily useful for reading bit-field values from structures that may change between kernel versions.

Note that the return value is a constant which is known at compile time. If the field has a variable offset then `FIELD_BYTE_OFFSET`, `FIELD_LSHIFT_U64`, and `FIELD_RSHIFT_U64` are not supported. Similarly, if the field has a variable size then `FIELD_BYTE_SIZE`, `FIELD_LSHIFT_U64`, and `FIELD_RSHIFT_U64` are not supported.

For example, `__builtin_preserve_field_info` can be used to reliably extract bit-field values from a structure that may change between kernel versions:

```
struct S
{
  short a;
  int x:7;
  int y:5;
};

int
read_y (struct S *arg)
{
  unsigned long long val;
  unsigned int offset
    = __builtin_preserve_field_info (arg->y, FIELD_BYTE_OFFSET);
  unsigned int size
    = __builtin_preserve_field_info (arg->y, FIELD_BYTE_SIZE);

  /* Read size bytes from arg + offset into val.  */
  bpf_probe_read (&val, size, arg + offset);

  val <<= __builtin_preserve_field_info (arg->y, FIELD_LSHIFT_U64);

  if (__builtin_preserve_field_info (arg->y, FIELD_SIGNEDNESS))
    val = ((long long) val
           >> __builtin_preserve_field_info (arg->y, FIELD_RSHIFT_U64));
  else
    val >>= __builtin_preserve_field_info (arg->y, FIELD_RSHIFT_U64);

  return val;
}
```

`unsigned int __builtin_preserve_enum_value (`*type*`, `*enum*`, unsigned int `*kind*`)` [Built-in Function]

BPF Compile Once-Run Everywhere (CO-RE) support. This builtin collects enum information and creates a CO-RE relocation relative to *enum* that should be of *type*. The *kind* specifies the action performed.

The following values are supported for *kind*:

`ENUM_VALUE_EXISTS = 0`
: The return value is either 0 or 1 depending if the enum value exists in the target.

`ENUM_VALUE = 1`
: The return value is the enum value in the target kernel.

`unsigned int __builtin_btf_type_id (type, unsigned int kind)` [Built-in Function]

BPF Compile Once-Run Everywhere (CO-RE) support. This builtin is used to get the BTF type ID of a specified *type*. Depending on the *kind* argument, it either returns the ID of the local BTF information, or the BTF type ID in the target kernel.

The following values are supported for *kind*:

`BTF_TYPE_ID_LOCAL = 0`
: Return the local BTF type ID. Always succeeds.

`BTF_TYPE_ID_TARGET = 1`
: Return the target BTF type ID. If *type* does not exist in the target, returns 0.

`unsigned int __builtin_preserve_type_info (type, unsigned int kind)` [Built-in Function]

BPF Compile Once-Run Everywhere (CO-RE) support. This builtin performs named type (struct/union/enum/typedef) verifications. The type of verification depends on the *kind* argument provided. This builtin always returns 0 if *type* does not exist in the target kernel.

The following values are supported for *kind*:

`BTF_TYPE_EXISTS = 0`
: Checks if *type* exists in the target.

`BTF_TYPE_MATCHES = 1`
: Checks if *type* matches the local definition in the target kernel.

`BTF_TYPE_SIZE = 2`
: Returns the size of the *type* within the target.

7.13.11 FR-V Built-in Functions

GCC provides many FR-V-specific built-in functions. In general, these functions are intended to be compatible with those described by *FR-V Family, Softune C/C++ Compiler Manual (V6), Fujitsu Semiconductor*. The two exceptions are `__MDUNPACKH` and `__MBTOHE`, the GCC forms of which pass 128-bit values by pointer rather than by value.

Most of the functions are named after specific FR-V instructions. Such functions are said to be "directly mapped" and are summarized here in tabular form.

7.13.11.1 Argument Types

The arguments to the built-in functions can be divided into three groups: register numbers, compile-time constants and run-time values. In order to make this classification clear at a glance, the arguments and return values are given the following pseudo types:

Pseudo type	Real C type	Constant?	Description
`uh`	`unsigned short`	No	an unsigned halfword
`uw1`	`unsigned int`	No	an unsigned word
`sw1`	`int`	No	a signed word
`uw2`	`unsigned long long`	No	an unsigned doubleword
`sw2`	`long long`	No	a signed doubleword

`const`	`int`	Yes	an integer constant
`acc`	`int`	Yes	an ACC register number
`iacc`	`int`	Yes	an IACC register number

These pseudo types are not defined by GCC, they are simply a notational convenience used in this manual.

Arguments of type `uh`, `uw1`, `sw1`, `uw2` and `sw2` are evaluated at run time. They correspond to register operands in the underlying FR-V instructions.

`const` arguments represent immediate operands in the underlying FR-V instructions. They must be compile-time constants.

`acc` arguments are evaluated at compile time and specify the number of an accumulator register. For example, an `acc` argument of 2 selects the ACC2 register.

`iacc` arguments are similar to `acc` arguments but specify the number of an IACC register. See see Section 7.13.11.5 [Other Built-in Functions], page 891, for more details.

7.13.11.2 Directly-Mapped Integer Functions

The functions listed below map directly to FR-V I-type instructions.

Function prototype	Example usage	Assembly output
`sw1 __ADDSS (sw1, sw1)`	*c* `= __ADDSS (`*a*`,` *b*`)`	`ADDSS` *a*`,`*b*`,`*c*
`sw1 __SCAN (sw1, sw1)`	*c* `= __SCAN (`*a*`,` *b*`)`	`SCAN` *a*`,`*b*`,`*c*
`sw1 __SCUTSS (sw1)`	*b* `= __SCUTSS (`*a*`)`	`SCUTSS` *a*`,`*b*
`sw1 __SLASS (sw1, sw1)`	*c* `= __SLASS (`*a*`,` *b*`)`	`SLASS` *a*`,`*b*`,`*c*
`void __SMASS (sw1, sw1)`	`__SMASS (`*a*`,` *b*`)`	`SMASS` *a*`,`*b*
`void __SMSSS (sw1, sw1)`	`__SMSSS (`*a*`,` *b*`)`	`SMSSS` *a*`,`*b*
`void __SMU (sw1, sw1)`	`__SMU (`*a*`,` *b*`)`	`SMU` *a*`,`*b*
`sw2 __SMUL (sw1, sw1)`	*c* `= __SMUL (`*a*`,` *b*`)`	`SMUL` *a*`,`*b*`,`*c*
`sw1 __SUBSS (sw1, sw1)`	*c* `= __SUBSS (`*a*`,` *b*`)`	`SUBSS` *a*`,`*b*`,`*c*
`uw2 __UMUL (uw1, uw1)`	*c* `= __UMUL (`*a*`,` *b*`)`	`UMUL` *a*`,`*b*`,`*c*

7.13.11.3 Directly-Mapped Media Functions

The functions listed below map directly to FR-V M-type instructions.

Function prototype	Example usage	Assembly output
`uw1 __MABSHS (sw1)`	*b* `= __MABSHS (`*a*`)`	`MABSHS` *a*`,`*b*
`void __MADDACCS (acc, acc)`	`__MADDACCS (`*b*`,` *a*`)`	`MADDACCS` *a*`,`*b*
`sw1 __MADDHSS (sw1, sw1)`	*c* `= __MADDHSS (`*a*`,` *b*`)`	`MADDHSS` *a*`,`*b*`,`*c*
`uw1 __MADDHUS (uw1, uw1)`	*c* `= __MADDHUS (`*a*`,` *b*`)`	`MADDHUS` *a*`,`*b*`,`*c*
`uw1 __MAND (uw1, uw1)`	*c* `= __MAND (`*a*`,` *b*`)`	`MAND` *a*`,`*b*`,`*c*
`void __MASACCS (acc, acc)`	`__MASACCS (`*b*`,` *a*`)`	`MASACCS` *a*`,`*b*
`uw1 __MAVEH (uw1, uw1)`	*c* `= __MAVEH (`*a*`,` *b*`)`	`MAVEH` *a*`,`*b*`,`*c*
`uw2 __MBTOH (uw1)`	*b* `= __MBTOH (`*a*`)`	`MBTOH` *a*`,`*b*
`void __MBTOHE (uw1 *, uw1)`	`__MBTOHE (&`*b*`,` *a*`)`	`MBTOHE` *a*`,`*b*
`void __MCLRACC (acc)`	`__MCLRACC (`*a*`)`	`MCLRACC` *a*
`void __MCLRACCA (void)`	`__MCLRACCA ()`	`MCLRACCA`
`uw1 __Mcop1 (uw1, uw1)`	*c* `= __Mcop1 (`*a*`,` *b*`)`	`Mcop1` *a*`,`*b*`,`*c*
`uw1 __Mcop2 (uw1, uw1)`	*c* `= __Mcop2 (`*a*`,` *b*`)`	`Mcop2` *a*`,`*b*`,`*c*
`uw1 __MCPLHI (uw2, const)`	*c* `= __MCPLHI (`*a*`,` *b*`)`	`MCPLHI` *a*`,#`*b*`,`*c*

uw1 __MCPLI (uw2, const)	*c* = __MCPLI (*a*, *b*)	MCPLI *a*,#*b*,*c*
void __MCPXIS (acc, sw1, sw1)	__MCPXIS (*c*, *a*, *b*)	MCPXIS *a*,*b*,*c*
void __MCPXIU (acc, uw1, uw1)	__MCPXIU (*c*, *a*, *b*)	MCPXIU *a*,*b*,*c*
void __MCPXRS (acc, sw1, sw1)	__MCPXRS (*c*, *a*, *b*)	MCPXRS *a*,*b*,*c*
void __MCPXRU (acc, uw1, uw1)	__MCPXRU (*c*, *a*, *b*)	MCPXRU *a*,*b*,*c*
uw1 __MCUT (acc, uw1)	*c* = __MCUT (*a*, *b*)	MCUT *a*,*b*,*c*
uw1 __MCUTSS (acc, sw1)	*c* = __MCUTSS (*a*, *b*)	MCUTSS *a*,*b*,*c*
void __MDADDACCS (acc, acc)	__MDADDACCS (*b*, *a*)	MDADDACCS *a*,*b*
void __MDASACCS (acc, acc)	__MDASACCS (*b*, *a*)	MDASACCS *a*,*b*
uw2 __MDCUTSSI (acc, const)	*c* = __MDCUTSSI (*a*, *b*)	MDCUTSSI *a*,#*b*,*c*
uw2 __MDPACKH (uw2, uw2)	*c* = __MDPACKH (*a*, *b*)	MDPACKH *a*,*b*,*c*
uw2 __MDROTLI (uw2, const)	*c* = __MDROTLI (*a*, *b*)	MDROTLI *a*,#*b*,*c*
void __MDSUBACCS (acc, acc)	__MDSUBACCS (*b*, *a*)	MDSUBACCS *a*,*b*
void __MDUNPACKH (uw1 *, uw2)	__MDUNPACKH (&*b*, *a*)	MDUNPACKH *a*,*b*
uw2 __MEXPDHD (uw1, const)	*c* = __MEXPDHD (*a*, *b*)	MEXPDHD *a*,#*b*,*c*
uw1 __MEXPDHW (uw1, const)	*c* = __MEXPDHW (*a*, *b*)	MEXPDHW *a*,#*b*,*c*
uw1 __MHDSETH (uw1, const)	*c* = __MHDSETH (*a*, *b*)	MHDSETH *a*,#*b*,*c*
sw1 __MHDSETS (const)	*b* = __MHDSETS (*a*)	MHDSETS #*a*,*b*
uw1 __MHSETHIH (uw1, const)	*b* = __MHSETHIH (*b*, *a*)	MHSETHIH #*a*,*b*
sw1 __MHSETHIS (sw1, const)	*b* = __MHSETHIS (*b*, *a*)	MHSETHIS #*a*,*b*
uw1 __MHSETLOH (uw1, const)	*b* = __MHSETLOH (*b*, *a*)	MHSETLOH #*a*,*b*
sw1 __MHSETLOS (sw1, const)	*b* = __MHSETLOS (*b*, *a*)	MHSETLOS #*a*,*b*
uw1 __MHTOB (uw2)	*b* = __MHTOB (*a*)	MHTOB *a*,*b*
void __MMACHS (acc, sw1, sw1)	__MMACHS (*c*, *a*, *b*)	MMACHS *a*,*b*,*c*
void __MMACHU (acc, uw1, uw1)	__MMACHU (*c*, *a*, *b*)	MMACHU *a*,*b*,*c*
void __MMRDHS (acc, sw1, sw1)	__MMRDHS (*c*, *a*, *b*)	MMRDHS *a*,*b*,*c*
void __MMRDHU (acc, uw1, uw1)	__MMRDHU (*c*, *a*, *b*)	MMRDHU *a*,*b*,*c*
void __MMULHS (acc, sw1, sw1)	__MMULHS (*c*, *a*, *b*)	MMULHS *a*,*b*,*c*
void __MMULHU (acc, uw1, uw1)	__MMULHU (*c*, *a*, *b*)	MMULHU *a*,*b*,*c*
void __MMULXHS (acc, sw1, sw1)	__MMULXHS (*c*, *a*, *b*)	MMULXHS *a*,*b*,*c*
void __MMULXHU (acc, uw1, uw1)	__MMULXHU (*c*, *a*, *b*)	MMULXHU *a*,*b*,*c*
uw1 __MNOT (uw1)	*b* = __MNOT (*a*)	MNOT *a*,*b*
uw1 __MOR (uw1, uw1)	*c* = __MOR (*a*, *b*)	MOR *a*,*b*,*c*
uw1 __MPACKH (uh, uh)	*c* = __MPACKH (*a*, *b*)	MPACKH *a*,*b*,*c*
sw2 __MQADDHSS (sw2, sw2)	*c* = __MQADDHSS (*a*, *b*)	MQADDHSS *a*,*b*,*c*
uw2 __MQADDHUS (uw2, uw2)	*c* = __MQADDHUS (*a*, *b*)	MQADDHUS *a*,*b*,*c*
void __MQCPXIS (acc, sw2, sw2)	__MQCPXIS (*c*, *a*, *b*)	MQCPXIS *a*,*b*,*c*
void __MQCPXIU (acc, uw2, uw2)	__MQCPXIU (*c*, *a*, *b*)	MQCPXIU *a*,*b*,*c*
void __MQCPXRS (acc, sw2, sw2)	__MQCPXRS (*c*, *a*, *b*)	MQCPXRS *a*,*b*,*c*
void __MQCPXRU (acc, uw2, uw2)	__MQCPXRU (*c*, *a*, *b*)	MQCPXRU *a*,*b*,*c*
sw2 __MQLCLRHS (sw2, sw2)	*c* = __MQLCLRHS (*a*, *b*)	MQLCLRHS *a*,*b*,*c*
sw2 __MQLMTHS (sw2, sw2)	*c* = __MQLMTHS (*a*, *b*)	MQLMTHS *a*,*b*,*c*
void __MQMACHS (acc, sw2, sw2)	__MQMACHS (*c*, *a*, *b*)	MQMACHS *a*,*b*,*c*
void __MQMACHU (acc, uw2, uw2)	__MQMACHU (*c*, *a*, *b*)	MQMACHU *a*,*b*,*c*
void __MQMACXHS (acc, sw2, sw2)	__MQMACXHS (*c*, *a*, *b*)	MQMACXHS *a*,*b*,*c*
void __MQMULHS (acc, sw2, sw2)	__MQMULHS (*c*, *a*, *b*)	MQMULHS *a*,*b*,*c*
void __MQMULHU (acc, uw2, uw2)	__MQMULHU (*c*, *a*, *b*)	MQMULHU *a*,*b*,*c*

void __MQMULXHS (acc, sw2, sw2)	__MQMULXHS (*c*, *a*, *b*)	MQMULXHS *a*,*b*,*c*
void __MQMULXHU (acc, uw2, uw2)	__MQMULXHU (*c*, *a*, *b*)	MQMULXHU *a*,*b*,*c*
sw2 __MQSATHS (sw2, sw2)	*c* = __MQSATHS (*a*, *b*)	MQSATHS *a*,*b*,*c*
uw2 __MQSLLHI (uw2, int)	*c* = __MQSLLHI (*a*, *b*)	MQSLLHI *a*,*b*,*c*
sw2 __MQSRAHI (sw2, int)	*c* = __MQSRAHI (*a*, *b*)	MQSRAHI *a*,*b*,*c*
sw2 __MQSUBHSS (sw2, sw2)	*c* = __MQSUBHSS (*a*, *b*)	MQSUBHSS *a*,*b*,*c*
uw2 __MQSUBHUS (uw2, uw2)	*c* = __MQSUBHUS (*a*, *b*)	MQSUBHUS *a*,*b*,*c*
void __MQXMACHS (acc, sw2, sw2)	__MQXMACHS (*c*, *a*, *b*)	MQXMACHS *a*,*b*,*c*
void __MQXMACXHS (acc, sw2, sw2)	__MQXMACXHS (*c*, *a*, *b*)	MQXMACXHS *a*,*b*,*c*
uw1 __MRDACC (acc)	*b* = __MRDACC (*a*)	MRDACC *a*,*b*
uw1 __MRDACCG (acc)	*b* = __MRDACCG (*a*)	MRDACCG *a*,*b*
uw1 __MROTLI (uw1, const)	*c* = __MROTLI (*a*, *b*)	MROTLI *a*,#*b*,*c*
uw1 __MROTRI (uw1, const)	*c* = __MROTRI (*a*, *b*)	MROTRI *a*,#*b*,*c*
sw1 __MSATHS (sw1, sw1)	*c* = __MSATHS (*a*, *b*)	MSATHS *a*,*b*,*c*
uw1 __MSATHU (uw1, uw1)	*c* = __MSATHU (*a*, *b*)	MSATHU *a*,*b*,*c*
uw1 __MSLLHI (uw1, const)	*c* = __MSLLHI (*a*, *b*)	MSLLHI *a*,#*b*,*c*
sw1 __MSRAHI (sw1, const)	*c* = __MSRAHI (*a*, *b*)	MSRAHI *a*,#*b*,*c*
uw1 __MSRLHI (uw1, const)	*c* = __MSRLHI (*a*, *b*)	MSRLHI *a*,#*b*,*c*
void __MSUBACCS (acc, acc)	__MSUBACCS (*b*, *a*)	MSUBACCS *a*,*b*
sw1 __MSUBHSS (sw1, sw1)	*c* = __MSUBHSS (*a*, *b*)	MSUBHSS *a*,*b*,*c*
uw1 __MSUBHUS (uw1, uw1)	*c* = __MSUBHUS (*a*, *b*)	MSUBHUS *a*,*b*,*c*
void __MTRAP (void)	__MTRAP ()	MTRAP
uw2 __MUNPACKH (uw1)	*b* = __MUNPACKH (*a*)	MUNPACKH *a*,*b*
uw1 __MWCUT (uw2, uw1)	*c* = __MWCUT (*a*, *b*)	MWCUT *a*,*b*,*c*
void __MWTACC (acc, uw1)	__MWTACC (*b*, *a*)	MWTACC *a*,*b*
void __MWTACCG (acc, uw1)	__MWTACCG (*b*, *a*)	MWTACCG *a*,*b*
uw1 __MXOR (uw1, uw1)	*c* = __MXOR (*a*, *b*)	MXOR *a*,*b*,*c*

7.13.11.4 Raw Read/Write Functions

This sections describes built-in functions related to read and write instructions to access memory. These functions generate `membar` instructions to flush the I/O load and stores where appropriate, as described in Fujitsu's manual described above.

unsigned char __builtin_read8 (void **data*)
unsigned short __builtin_read16 (void **data*)
unsigned long __builtin_read32 (void **data*)
unsigned long long __builtin_read64 (void **data*)
void __builtin_write8 (void **data*, unsigned char *datum*)
void __builtin_write16 (void **data*, unsigned short *datum*)
void __builtin_write32 (void **data*, unsigned long *datum*)
void __builtin_write64 (void **data*, unsigned long long *datum*)

7.13.11.5 Other Built-in Functions

This section describes built-in functions that are not named after a specific FR-V instruction.

`sw2 __IACCreadll (iacc` *reg*`)`
: Return the full 64-bit value of IACC0. The *reg* argument is reserved for future expansion and must be 0.

`sw1 __IACCreadl (iacc` *reg*`)`
: Return the value of IACC0H if *reg* is 0 and IACC0L if *reg* is 1. Other values of *reg* are rejected as invalid.

`void __IACCsetll (iacc` *reg*`, sw2` *x*`)`
: Set the full 64-bit value of IACC0 to *x*. The *reg* argument is reserved for future expansion and must be 0.

`void __IACCsetl (iacc` *reg*`, sw1` *x*`)`
: Set IACC0H to *x* if *reg* is 0 and IACC0L to *x* if *reg* is 1. Other values of *reg* are rejected as invalid.

`void __data_prefetch0 (const void *`*x*`)`
: Use the `dcpl` instruction to load the contents of address *x* into the data cache.

`void __data_prefetch (const void *`*x*`)`
: Use the `nldub` instruction to load the contents of address *x* into the data cache. The instruction is issued in slot I1.

7.13.12 LoongArch Base Built-in Functions

These built-in functions are available for LoongArch.

7.13.12.1 Data Types

- `imm0_31`, a compile-time constant in range 0 to 31;
- `imm0_16383`, a compile-time constant in range 0 to 16383;
- `imm0_32767`, a compile-time constant in range 0 to 32767;
- `imm_n2048_2047`, a compile-time constant in range -2048 to 2047;

7.13.12.2 Directly-mapped Builtin Functions

The intrinsics provided are listed below:

```
unsigned int __builtin_loongarch_movfcsr2gr (imm0_31)
void __builtin_loongarch_movgr2fcsr (imm0_31, unsigned int)
void __builtin_loongarch_cacop_d (imm0_31, unsigned long int, imm_n2048_2047)
unsigned int __builtin_loongarch_cpucfg (unsigned int)
void __builtin_loongarch_asrtle_d (long int, long int)
void __builtin_loongarch_asrtgt_d (long int, long int)
long int __builtin_loongarch_lddir_d (long int, imm0_31)
void __builtin_loongarch_ldpte_d (long int, imm0_31)

int __builtin_loongarch_crc_w_b_w (char, int)
int __builtin_loongarch_crc_w_h_w (short, int)
int __builtin_loongarch_crc_w_w_w (int, int)
int __builtin_loongarch_crc_w_d_w (long int, int)
int __builtin_loongarch_crcc_w_b_w (char, int)
int __builtin_loongarch_crcc_w_h_w (short, int)
int __builtin_loongarch_crcc_w_w_w (int, int)
int __builtin_loongarch_crcc_w_d_w (long int, int)
```

```
unsigned int __builtin_loongarch_csrrd_w (imm0_16383)
unsigned int __builtin_loongarch_csrwr_w (unsigned int, imm0_16383)
unsigned int __builtin_loongarch_csrxchg_w (unsigned int, unsigned int, imm0_16383)
unsigned long int __builtin_loongarch_csrrd_d (imm0_16383)
unsigned long int __builtin_loongarch_csrwr_d (unsigned long int, imm0_16383)
unsigned long int __builtin_loongarch_csrxchg_d (unsigned long int, unsigned long int, imm0_16383)

unsigned char __builtin_loongarch_iocsrrd_b (unsigned int)
unsigned short __builtin_loongarch_iocsrrd_h (unsigned int)
unsigned int __builtin_loongarch_iocsrrd_w (unsigned int)
unsigned long int __builtin_loongarch_iocsrrd_d (unsigned int)
void __builtin_loongarch_iocsrwr_b (unsigned char, unsigned int)
void __builtin_loongarch_iocsrwr_h (unsigned short, unsigned int)
void __builtin_loongarch_iocsrwr_w (unsigned int, unsigned int)
void __builtin_loongarch_iocsrwr_d (unsigned long int, unsigned int)

void __builtin_loongarch_dbar (imm0_32767)
void __builtin_loongarch_ibar (imm0_32767)

void __builtin_loongarch_syscall (imm0_32767)
void __builtin_loongarch_break (imm0_32767)
```

These intrinsic functions are available by using `-mfrecipe`.

```
float __builtin_loongarch_frecipe_s (float);
double  __builtin_loongarch_frecipe_d (double);
float __builtin_loongarch_frsqrte_s (float);
double  __builtin_loongarch_frsqrte_d (double);
```

*Note:*Since the control register is divided into 32-bit and 64-bit, but the access instruction is not distinguished. So GCC renames the control instructions when implementing intrinsics.

Take the csrrd instruction as an example, built-in functions are implemented as follows:

```
__builtin_loongarch_csrrd_w  // When reading the 32-bit control register use.
__builtin_loongarch_csrrd_d  // When reading the 64-bit control register use.
```

For the convenience of use, the built-in functions are encapsulated, the encapsulated functions and `__drdtime_t, __rdtime_t` are defined in the `larchintrin.h`. So if you call the following function you need to include `larchintrin.h`.

```
 typedef struct drdtime{
        unsigned long dvalue;
        unsigned long dtimeid;
 } __drdtime_t;

 typedef struct rdtime{
        unsigned int value;
        unsigned int timeid;
 } __rdtime_t;
__drdtime_t __rdtime_d (void)
__rdtime_t  __rdtimel_w (void)
__rdtime_t  __rdtimeh_w (void)
unsigned int  __movfcsr2gr (imm0_31)
void __movgr2fcsr (imm0_31, unsigned int)
void __cacop_d (imm0_31, unsigned long, imm_n2048_2047)
unsigned int  __cpucfg (unsigned int)
void __asrtle_d (long int, long int)
void __asrtgt_d (long int, long int)
long int  __lddir_d (long int, imm0_31)
void __ldpte_d (long int, imm0_31)
```

```
int  __crc_w_b_w (char, int)
int  __crc_w_h_w (short, int)
int  __crc_w_w_w (int, int)
int  __crc_w_d_w (long int, int)
int  __crcc_w_b_w (char, int)
int  __crcc_w_h_w (short, int)
int  __crcc_w_w_w (int, int)
int  __crcc_w_d_w (long int, int)

unsigned int  __csrrd_w (imm0_16383)
unsigned int  __csrwr_w (unsigned int, imm0_16383)
unsigned int  __csrxchg_w (unsigned int, unsigned int, imm0_16383)
unsigned long  __csrrd_d (imm0_16383)
unsigned long  __csrwr_d (unsigned long, imm0_16383)
unsigned long  __csrxchg_d (unsigned long, unsigned long, imm0_16383)

unsigned char   __iocsrrd_b (unsigned int)
unsigned short  __iocsrrd_h (unsigned int)
unsigned int  __iocsrrd_w (unsigned int)
unsigned long  __iocsrrd_d (unsigned int)
void __iocsrwr_b (unsigned char, unsigned int)
void __iocsrwr_h (unsigned short, unsigned int)
void __iocsrwr_w (unsigned int, unsigned int)
void __iocsrwr_d (unsigned long, unsigned int)

void __dbar (imm0_32767)
void __ibar (imm0_32767)

void __syscall (imm0_32767)
void __break (imm0_32767)
```

7.13.12.3 Directly-mapped Division Builtin Functions

These intrinsic functions are available by including `larchintrin.h` and using `-mfrecipe`.

```
float __frecipe_s (float);
double __frecipe_d (double);
float __frsqrte_s (float);
double __frsqrte_d (double);
```

7.13.12.4 Other Builtin Functions

Additional built-in functions are available for LoongArch family processors to efficiently use 128-bit floating-point (__float128) values.

The following are the basic built-in functions supported.

```
__float128 __builtin_fabsq (__float128);
__float128 __builtin_copysignq (__float128, __float128);
__float128 __builtin_infq (void);
__float128 __builtin_huge_valq (void);
__float128 __builtin_nanq (void);
__float128 __builtin_nansq (void);
```

Returns the value that is currently set in the ‘`tp`’ register.

```
void * __builtin_thread_pointer (void)
```

7.13.13 LoongArch SX Vector Intrinsics

GCC provides intrinsics to access the LSX (Loongson SIMD Extension) instructions. The interface is made available by including `<lsxintrin.h>` and using `-mlsx`.

7.13.13.1 SX Data Types

The following vectors typedefs are included in `lsxintrin.h`:

- `__m128i`, a 128-bit vector of fixed point;
- `__m128`, a 128-bit vector of single precision floating point;
- `__m128d`, a 128-bit vector of double precision floating point.

Instructions and corresponding built-ins may have additional restrictions and/or input/output values manipulated:

- `imm0_1`, an integer literal in range 0 to 1;
- `imm0_3`, an integer literal in range 0 to 3;
- `imm0_7`, an integer literal in range 0 to 7;
- `imm0_15`, an integer literal in range 0 to 15;
- `imm0_31`, an integer literal in range 0 to 31;
- `imm0_63`, an integer literal in range 0 to 63;
- `imm0_127`, an integer literal in range 0 to 127;
- `imm0_255`, an integer literal in range 0 to 255;
- `imm_n16_15`, an integer literal in range -16 to 15;
- `imm_n128_127`, an integer literal in range -128 to 127;
- `imm_n256_255`, an integer literal in range -256 to 255;
- `imm_n512_511`, an integer literal in range -512 to 511;
- `imm_n1024_1023`, an integer literal in range -1024 to 1023;
- `imm_n2048_2047`, an integer literal in range -2048 to 2047.

7.13.13.2 Directly-mapped SX Builtin Functions

For convenience, GCC defines functions `__lsx_vrepli_{b/h/w/d}` and `__lsx_b[n]z_{v/b/h/w/d}`, which are implemented as follows:

```
a. __lsx_vrepli_{b/h/w/d}: Implemented the case where the highest
   bit of vldi instruction i13 is 1.

   i13[12] == 1'b0
   case i13[11:10] of :
     2'b00: __lsx_vrepli_b (imm_n512_511)
     2'b01: __lsx_vrepli_h (imm_n512_511)
     2'b10: __lsx_vrepli_w (imm_n512_511)
     2'b11: __lsx_vrepli_d (imm_n512_511)

b. __lsx_b[n]z_{v/b/h/w/d}: Since the vseteqz class directive
   cannot be used on its own, this function is defined.

   _lsx_bz_v  => vseteqz.v + bcnez
   _lsx_bnz_v => vsetnez.v + bcnez
   _lsx_bz_b  => vsetanyeqz.b + bcnez
   _lsx_bz_h  => vsetanyeqz.h + bcnez
   _lsx_bz_w  => vsetanyeqz.w + bcnez
   _lsx_bz_d  => vsetanyeqz.d + bcnez
   _lsx_bnz_b => vsetallnez.b + bcnez
   _lsx_bnz_h => vsetallnez.h + bcnez
```

```
 _lsx_bnz_w => vsetallnez.w + bcnez
 _lsx_bnz_d => vsetallnez.d + bcnez
eg:
  #include <lsxintrin.h>

  extern __m128i a;

  void
  test (void)
  {
    if (__lsx_bz_v (a))
      printf ("1\n");
    else
      printf ("2\n");
  }
```

Note: For directives where the intent operand is also the source operand (modifying only part of the bitfield of the intent register), the first parameter in the builtin call function is used as the intent operand.

```
eg:
  #include <lsxintrin.h>

  extern __m128i dst;
  extern int src;

  void
  test (void)
  {
    dst = __lsx_vinsgr2vr_b (dst, src, 3);
  }
```

The intrinsics provided are listed below:

```
int __lsx_bnz_b (__m128i);
int __lsx_bnz_d (__m128i);
int __lsx_bnz_h (__m128i);
int __lsx_bnz_v (__m128i);
int __lsx_bnz_w (__m128i);
int __lsx_bz_b (__m128i);
int __lsx_bz_d (__m128i);
int __lsx_bz_h (__m128i);
int __lsx_bz_v (__m128i);
int __lsx_bz_w (__m128i);
__m128i __lsx_vabsd_b (__m128i, __m128i);
__m128i __lsx_vabsd_bu (__m128i, __m128i);
__m128i __lsx_vabsd_d (__m128i, __m128i);
__m128i __lsx_vabsd_du (__m128i, __m128i);
__m128i __lsx_vabsd_h (__m128i, __m128i);
__m128i __lsx_vabsd_hu (__m128i, __m128i);
__m128i __lsx_vabsd_w (__m128i, __m128i);
__m128i __lsx_vabsd_wu (__m128i, __m128i);
__m128i __lsx_vadda_b (__m128i, __m128i);
__m128i __lsx_vadda_d (__m128i, __m128i);
__m128i __lsx_vadda_h (__m128i, __m128i);
__m128i __lsx_vadda_w (__m128i, __m128i);
__m128i __lsx_vadd_b (__m128i, __m128i);
__m128i __lsx_vadd_d (__m128i, __m128i);
__m128i __lsx_vadd_h (__m128i, __m128i);
__m128i __lsx_vaddi_bu (__m128i, imm0_31);
```

```
__m128i __lsx_vaddi_du (__m128i, imm0_31);
__m128i __lsx_vaddi_hu (__m128i, imm0_31);
__m128i __lsx_vaddi_wu (__m128i, imm0_31);
__m128i __lsx_vadd_q (__m128i, __m128i);
__m128i __lsx_vadd_w (__m128i, __m128i);
__m128i __lsx_vaddwev_d_w (__m128i, __m128i);
__m128i __lsx_vaddwev_d_wu (__m128i, __m128i);
__m128i __lsx_vaddwev_d_wu_w (__m128i, __m128i);
__m128i __lsx_vaddwev_h_b (__m128i, __m128i);
__m128i __lsx_vaddwev_h_bu (__m128i, __m128i);
__m128i __lsx_vaddwev_h_bu_b (__m128i, __m128i);
__m128i __lsx_vaddwev_q_d (__m128i, __m128i);
__m128i __lsx_vaddwev_q_du (__m128i, __m128i);
__m128i __lsx_vaddwev_q_du_d (__m128i, __m128i);
__m128i __lsx_vaddwev_w_h (__m128i, __m128i);
__m128i __lsx_vaddwev_w_hu (__m128i, __m128i);
__m128i __lsx_vaddwev_w_hu_h (__m128i, __m128i);
__m128i __lsx_vaddwod_d_w (__m128i, __m128i);
__m128i __lsx_vaddwod_d_wu (__m128i, __m128i);
__m128i __lsx_vaddwod_d_wu_w (__m128i, __m128i);
__m128i __lsx_vaddwod_h_b (__m128i, __m128i);
__m128i __lsx_vaddwod_h_bu (__m128i, __m128i);
__m128i __lsx_vaddwod_h_bu_b (__m128i, __m128i);
__m128i __lsx_vaddwod_q_d (__m128i, __m128i);
__m128i __lsx_vaddwod_q_du (__m128i, __m128i);
__m128i __lsx_vaddwod_q_du_d (__m128i, __m128i);
__m128i __lsx_vaddwod_w_h (__m128i, __m128i);
__m128i __lsx_vaddwod_w_hu (__m128i, __m128i);
__m128i __lsx_vaddwod_w_hu_h (__m128i, __m128i);
__m128i __lsx_vandi_b (__m128i, imm0_255);
__m128i __lsx_vandn_v (__m128i, __m128i);
__m128i __lsx_vand_v (__m128i, __m128i);
__m128i __lsx_vavg_b (__m128i, __m128i);
__m128i __lsx_vavg_bu (__m128i, __m128i);
__m128i __lsx_vavg_d (__m128i, __m128i);
__m128i __lsx_vavg_du (__m128i, __m128i);
__m128i __lsx_vavg_h (__m128i, __m128i);
__m128i __lsx_vavg_hu (__m128i, __m128i);
__m128i __lsx_vavgr_b (__m128i, __m128i);
__m128i __lsx_vavgr_bu (__m128i, __m128i);
__m128i __lsx_vavgr_d (__m128i, __m128i);
__m128i __lsx_vavgr_du (__m128i, __m128i);
__m128i __lsx_vavgr_h (__m128i, __m128i);
__m128i __lsx_vavgr_hu (__m128i, __m128i);
__m128i __lsx_vavgr_w (__m128i, __m128i);
__m128i __lsx_vavgr_wu (__m128i, __m128i);
__m128i __lsx_vavg_w (__m128i, __m128i);
__m128i __lsx_vavg_wu (__m128i, __m128i);
__m128i __lsx_vbitclr_b (__m128i, __m128i);
__m128i __lsx_vbitclr_d (__m128i, __m128i);
__m128i __lsx_vbitclr_h (__m128i, __m128i);
__m128i __lsx_vbitclri_b (__m128i, imm0_7);
__m128i __lsx_vbitclri_d (__m128i, imm0_63);
__m128i __lsx_vbitclri_h (__m128i, imm0_15);
__m128i __lsx_vbitclri_w (__m128i, imm0_31);
__m128i __lsx_vbitclr_w (__m128i, __m128i);
__m128i __lsx_vbitrev_b (__m128i, __m128i);
__m128i __lsx_vbitrev_d (__m128i, __m128i);
```

```
__m128i __lsx_vbitrev_h (__m128i, __m128i);
__m128i __lsx_vbitrevi_b (__m128i, imm0_7);
__m128i __lsx_vbitrevi_d (__m128i, imm0_63);
__m128i __lsx_vbitrevi_h (__m128i, imm0_15);
__m128i __lsx_vbitrevi_w (__m128i, imm0_31);
__m128i __lsx_vbitrev_w (__m128i, __m128i);
__m128i __lsx_vbitseli_b (__m128i, __m128i, imm0_255);
__m128i __lsx_vbitsel_v (__m128i, __m128i, __m128i);
__m128i __lsx_vbitset_b (__m128i, __m128i);
__m128i __lsx_vbitset_d (__m128i, __m128i);
__m128i __lsx_vbitset_h (__m128i, __m128i);
__m128i __lsx_vbitseti_b (__m128i, imm0_7);
__m128i __lsx_vbitseti_d (__m128i, imm0_63);
__m128i __lsx_vbitseti_h (__m128i, imm0_15);
__m128i __lsx_vbitseti_w (__m128i, imm0_31);
__m128i __lsx_vbitset_w (__m128i, __m128i);
__m128i __lsx_vbsll_v (__m128i, imm0_31);
__m128i __lsx_vbsrl_v (__m128i, imm0_31);
__m128i __lsx_vclo_b (__m128i);
__m128i __lsx_vclo_d (__m128i);
__m128i __lsx_vclo_h (__m128i);
__m128i __lsx_vclo_w (__m128i);
__m128i __lsx_vclz_b (__m128i);
__m128i __lsx_vclz_d (__m128i);
__m128i __lsx_vclz_h (__m128i);
__m128i __lsx_vclz_w (__m128i);
__m128i __lsx_vdiv_b (__m128i, __m128i);
__m128i __lsx_vdiv_bu (__m128i, __m128i);
__m128i __lsx_vdiv_d (__m128i, __m128i);
__m128i __lsx_vdiv_du (__m128i, __m128i);
__m128i __lsx_vdiv_h (__m128i, __m128i);
__m128i __lsx_vdiv_hu (__m128i, __m128i);
__m128i __lsx_vdiv_w (__m128i, __m128i);
__m128i __lsx_vdiv_wu (__m128i, __m128i);
__m128i __lsx_vexth_du_wu (__m128i);
__m128i __lsx_vexth_d_w (__m128i);
__m128i __lsx_vexth_h_b (__m128i);
__m128i __lsx_vexth_hu_bu (__m128i);
__m128i __lsx_vexth_q_d (__m128i);
__m128i __lsx_vexth_qu_du (__m128i);
__m128i __lsx_vexth_w_h (__m128i);
__m128i __lsx_vexth_wu_hu (__m128i);
__m128i __lsx_vextl_q_d (__m128i);
__m128i __lsx_vextl_qu_du (__m128i);
__m128i __lsx_vextrins_b (__m128i, __m128i, imm0_255);
__m128i __lsx_vextrins_d (__m128i, __m128i, imm0_255);
__m128i __lsx_vextrins_h (__m128i, __m128i, imm0_255);
__m128i __lsx_vextrins_w (__m128i, __m128i, imm0_255);
__m128d __lsx_vfadd_d (__m128d, __m128d);
__m128 __lsx_vfadd_s (__m128, __m128);
__m128i __lsx_vfclass_d (__m128d);
__m128i __lsx_vfclass_s (__m128);
__m128i __lsx_vfcmp_caf_d (__m128d, __m128d);
__m128i __lsx_vfcmp_caf_s (__m128, __m128);
__m128i __lsx_vfcmp_ceq_d (__m128d, __m128d);
__m128i __lsx_vfcmp_ceq_s (__m128, __m128);
__m128i __lsx_vfcmp_cle_d (__m128d, __m128d);
__m128i __lsx_vfcmp_cle_s (__m128, __m128);
```

```
__m128i __lsx_vfcmp_clt_d (__m128d, __m128d);
__m128i __lsx_vfcmp_clt_s (__m128, __m128);
__m128i __lsx_vfcmp_cne_d (__m128d, __m128d);
__m128i __lsx_vfcmp_cne_s (__m128, __m128);
__m128i __lsx_vfcmp_cor_d (__m128d, __m128d);
__m128i __lsx_vfcmp_cor_s (__m128, __m128);
__m128i __lsx_vfcmp_cueq_d (__m128d, __m128d);
__m128i __lsx_vfcmp_cueq_s (__m128, __m128);
__m128i __lsx_vfcmp_cule_d (__m128d, __m128d);
__m128i __lsx_vfcmp_cule_s (__m128, __m128);
__m128i __lsx_vfcmp_cult_d (__m128d, __m128d);
__m128i __lsx_vfcmp_cult_s (__m128, __m128);
__m128i __lsx_vfcmp_cun_d (__m128d, __m128d);
__m128i __lsx_vfcmp_cune_d (__m128d, __m128d);
__m128i __lsx_vfcmp_cune_s (__m128, __m128);
__m128i __lsx_vfcmp_cun_s (__m128, __m128);
__m128i __lsx_vfcmp_saf_d (__m128d, __m128d);
__m128i __lsx_vfcmp_saf_s (__m128, __m128);
__m128i __lsx_vfcmp_seq_d (__m128d, __m128d);
__m128i __lsx_vfcmp_seq_s (__m128, __m128);
__m128i __lsx_vfcmp_sle_d (__m128d, __m128d);
__m128i __lsx_vfcmp_sle_s (__m128, __m128);
__m128i __lsx_vfcmp_slt_d (__m128d, __m128d);
__m128i __lsx_vfcmp_slt_s (__m128, __m128);
__m128i __lsx_vfcmp_sne_d (__m128d, __m128d);
__m128i __lsx_vfcmp_sne_s (__m128, __m128);
__m128i __lsx_vfcmp_sor_d (__m128d, __m128d);
__m128i __lsx_vfcmp_sor_s (__m128, __m128);
__m128i __lsx_vfcmp_sueq_d (__m128d, __m128d);
__m128i __lsx_vfcmp_sueq_s (__m128, __m128);
__m128i __lsx_vfcmp_sule_d (__m128d, __m128d);
__m128i __lsx_vfcmp_sule_s (__m128, __m128);
__m128i __lsx_vfcmp_sult_d (__m128d, __m128d);
__m128i __lsx_vfcmp_sult_s (__m128, __m128);
__m128i __lsx_vfcmp_sun_d (__m128d, __m128d);
__m128i __lsx_vfcmp_sune_d (__m128d, __m128d);
__m128i __lsx_vfcmp_sune_s (__m128, __m128);
__m128i __lsx_vfcmp_sun_s (__m128, __m128);
__m128d __lsx_vfcvth_d_s (__m128);
__m128i __lsx_vfcvt_h_s (__m128, __m128);
__m128 __lsx_vfcvth_s_h (__m128i);
__m128d __lsx_vfcvtl_d_s (__m128);
__m128 __lsx_vfcvtl_s_h (__m128i);
__m128 __lsx_vfcvt_s_d (__m128d, __m128d);
__m128d __lsx_vfdiv_d (__m128d, __m128d);
__m128 __lsx_vfdiv_s (__m128, __m128);
__m128d __lsx_vffint_d_l (__m128i);
__m128d __lsx_vffint_d_lu (__m128i);
__m128d __lsx_vffinth_d_w (__m128i);
__m128d __lsx_vffintl_d_w (__m128i);
__m128 __lsx_vffint_s_l (__m128i, __m128i);
__m128 __lsx_vffint_s_w (__m128i);
__m128 __lsx_vffint_s_wu (__m128i);
__m128d __lsx_vflogb_d (__m128d);
__m128 __lsx_vflogb_s (__m128);
__m128d __lsx_vfmadd_d (__m128d, __m128d, __m128d);
__m128 __lsx_vfmadd_s (__m128, __m128, __m128);
__m128d __lsx_vfmaxa_d (__m128d, __m128d);
```

```
__m128 __lsx_vfmaxa_s (__m128, __m128);
__m128d __lsx_vfmax_d (__m128d, __m128d);
__m128 __lsx_vfmax_s (__m128, __m128);
__m128d __lsx_vfmina_d (__m128d, __m128d);
__m128 __lsx_vfmina_s (__m128, __m128);
__m128d __lsx_vfmin_d (__m128d, __m128d);
__m128 __lsx_vfmin_s (__m128, __m128);
__m128d __lsx_vfmsub_d (__m128d, __m128d, __m128d);
__m128 __lsx_vfmsub_s (__m128, __m128, __m128);
__m128d __lsx_vfmul_d (__m128d, __m128d);
__m128 __lsx_vfmul_s (__m128, __m128);
__m128d __lsx_vfnmadd_d (__m128d, __m128d, __m128d);
__m128 __lsx_vfnmadd_s (__m128, __m128, __m128);
__m128d __lsx_vfnmsub_d (__m128d, __m128d, __m128d);
__m128 __lsx_vfnmsub_s (__m128, __m128, __m128);
__m128d __lsx_vfrecip_d (__m128d);
__m128 __lsx_vfrecip_s (__m128);
__m128d __lsx_vfrint_d (__m128d);
__m128d __lsx_vfrintrm_d (__m128d);
__m128 __lsx_vfrintrm_s (__m128);
__m128d __lsx_vfrintrne_d (__m128d);
__m128 __lsx_vfrintrne_s (__m128);
__m128d __lsx_vfrintrp_d (__m128d);
__m128 __lsx_vfrintrp_s (__m128);
__m128d __lsx_vfrintrz_d (__m128d);
__m128 __lsx_vfrintrz_s (__m128);
__m128 __lsx_vfrint_s (__m128);
__m128d __lsx_vfrsqrt_d (__m128d);
__m128 __lsx_vfrsqrt_s (__m128);
__m128i __lsx_vfrstp_b (__m128i, __m128i, __m128i);
__m128i __lsx_vfrstp_h (__m128i, __m128i, __m128i);
__m128i __lsx_vfrstpi_b (__m128i, __m128i, imm0_31);
__m128i __lsx_vfrstpi_h (__m128i, __m128i, imm0_31);
__m128d __lsx_vfsqrt_d (__m128d);
__m128 __lsx_vfsqrt_s (__m128);
__m128d __lsx_vfsub_d (__m128d, __m128d);
__m128 __lsx_vfsub_s (__m128, __m128);
__m128i __lsx_vftinth_l_s (__m128);
__m128i __lsx_vftint_l_d (__m128d);
__m128i __lsx_vftintl_l_s (__m128);
__m128i __lsx_vftint_lu_d (__m128d);
__m128i __lsx_vftintrmh_l_s (__m128);
__m128i __lsx_vftintrm_l_d (__m128d);
__m128i __lsx_vftintrml_l_s (__m128);
__m128i __lsx_vftintrm_w_d (__m128d, __m128d);
__m128i __lsx_vftintrm_w_s (__m128);
__m128i __lsx_vftintrneh_l_s (__m128);
__m128i __lsx_vftintrne_l_d (__m128d);
__m128i __lsx_vftintrnel_l_s (__m128);
__m128i __lsx_vftintrne_w_d (__m128d, __m128d);
__m128i __lsx_vftintrne_w_s (__m128);
__m128i __lsx_vftintrph_l_s (__m128);
__m128i __lsx_vftintrp_l_d (__m128d);
__m128i __lsx_vftintrpl_l_s (__m128);
__m128i __lsx_vftintrp_w_d (__m128d, __m128d);
__m128i __lsx_vftintrp_w_s (__m128);
__m128i __lsx_vftintrzh_l_s (__m128);
__m128i __lsx_vftintrz_l_d (__m128d);
```

```
__m128i __lsx_vftintrzl_l_s (__m128);
__m128i __lsx_vftintrz_lu_d (__m128d);
__m128i __lsx_vftintrz_w_d (__m128d, __m128d);
__m128i __lsx_vftintrz_w_s (__m128);
__m128i __lsx_vftintrz_wu_s (__m128);
__m128i __lsx_vftint_w_d (__m128d, __m128d);
__m128i __lsx_vftint_w_s (__m128);
__m128i __lsx_vftint_wu_s (__m128);
__m128i __lsx_vhaddw_du_wu (__m128i, __m128i);
__m128i __lsx_vhaddw_d_w (__m128i, __m128i);
__m128i __lsx_vhaddw_h_b (__m128i, __m128i);
__m128i __lsx_vhaddw_hu_bu (__m128i, __m128i);
__m128i __lsx_vhaddw_q_d (__m128i, __m128i);
__m128i __lsx_vhaddw_qu_du (__m128i, __m128i);
__m128i __lsx_vhaddw_w_h (__m128i, __m128i);
__m128i __lsx_vhaddw_wu_hu (__m128i, __m128i);
__m128i __lsx_vhsubw_du_wu (__m128i, __m128i);
__m128i __lsx_vhsubw_d_w (__m128i, __m128i);
__m128i __lsx_vhsubw_h_b (__m128i, __m128i);
__m128i __lsx_vhsubw_hu_bu (__m128i, __m128i);
__m128i __lsx_vhsubw_q_d (__m128i, __m128i);
__m128i __lsx_vhsubw_qu_du (__m128i, __m128i);
__m128i __lsx_vhsubw_w_h (__m128i, __m128i);
__m128i __lsx_vhsubw_wu_hu (__m128i, __m128i);
__m128i __lsx_vilvh_b (__m128i, __m128i);
__m128i __lsx_vilvh_d (__m128i, __m128i);
__m128i __lsx_vilvh_h (__m128i, __m128i);
__m128i __lsx_vilvh_w (__m128i, __m128i);
__m128i __lsx_vilvl_b (__m128i, __m128i);
__m128i __lsx_vilvl_d (__m128i, __m128i);
__m128i __lsx_vilvl_h (__m128i, __m128i);
__m128i __lsx_vilvl_w (__m128i, __m128i);
__m128i __lsx_vinsgr2vr_b (__m128i, int, imm0_15);
__m128i __lsx_vinsgr2vr_d (__m128i, long int, imm0_1);
__m128i __lsx_vinsgr2vr_h (__m128i, int, imm0_7);
__m128i __lsx_vinsgr2vr_w (__m128i, int, imm0_3);
__m128i __lsx_vld (void *, imm_n2048_2047);
__m128i __lsx_vldi (imm_n1024_1023);
__m128i __lsx_vldrepl_b (void *, imm_n2048_2047);
__m128i __lsx_vldrepl_d (void *, imm_n256_255);
__m128i __lsx_vldrepl_h (void *, imm_n1024_1023);
__m128i __lsx_vldrepl_w (void *, imm_n512_511);
__m128i __lsx_vldx (void *, long int);
__m128i __lsx_vmadd_b (__m128i, __m128i, __m128i);
__m128i __lsx_vmadd_d (__m128i, __m128i, __m128i);
__m128i __lsx_vmadd_h (__m128i, __m128i, __m128i);
__m128i __lsx_vmadd_w (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwev_d_w (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwev_d_wu (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwev_d_wu_w (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwev_h_b (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwev_h_bu (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwev_h_bu_b (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwev_q_d (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwev_q_du (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwev_q_du_d (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwev_w_h (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwev_w_hu (__m128i, __m128i, __m128i);
```

```
__m128i __lsx_vmaddwev_w_hu_h (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwod_d_w (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwod_d_wu (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwod_d_wu_w (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwod_h_b (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwod_h_bu (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwod_h_bu_b (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwod_q_d (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwod_q_du (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwod_q_du_d (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwod_w_h (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwod_w_hu (__m128i, __m128i, __m128i);
__m128i __lsx_vmaddwod_w_hu_h (__m128i, __m128i, __m128i);
__m128i __lsx_vmax_b (__m128i, __m128i);
__m128i __lsx_vmax_bu (__m128i, __m128i);
__m128i __lsx_vmax_d (__m128i, __m128i);
__m128i __lsx_vmax_du (__m128i, __m128i);
__m128i __lsx_vmax_h (__m128i, __m128i);
__m128i __lsx_vmax_hu (__m128i, __m128i);
__m128i __lsx_vmaxi_b (__m128i, imm_n16_15);
__m128i __lsx_vmaxi_bu (__m128i, imm0_31);
__m128i __lsx_vmaxi_d (__m128i, imm_n16_15);
__m128i __lsx_vmaxi_du (__m128i, imm0_31);
__m128i __lsx_vmaxi_h (__m128i, imm_n16_15);
__m128i __lsx_vmaxi_hu (__m128i, imm0_31);
__m128i __lsx_vmaxi_w (__m128i, imm_n16_15);
__m128i __lsx_vmaxi_wu (__m128i, imm0_31);
__m128i __lsx_vmax_w (__m128i, __m128i);
__m128i __lsx_vmax_wu (__m128i, __m128i);
__m128i __lsx_vmin_b (__m128i, __m128i);
__m128i __lsx_vmin_bu (__m128i, __m128i);
__m128i __lsx_vmin_d (__m128i, __m128i);
__m128i __lsx_vmin_du (__m128i, __m128i);
__m128i __lsx_vmin_h (__m128i, __m128i);
__m128i __lsx_vmin_hu (__m128i, __m128i);
__m128i __lsx_vmini_b (__m128i, imm_n16_15);
__m128i __lsx_vmini_bu (__m128i, imm0_31);
__m128i __lsx_vmini_d (__m128i, imm_n16_15);
__m128i __lsx_vmini_du (__m128i, imm0_31);
__m128i __lsx_vmini_h (__m128i, imm_n16_15);
__m128i __lsx_vmini_hu (__m128i, imm0_31);
__m128i __lsx_vmini_w (__m128i, imm_n16_15);
__m128i __lsx_vmini_wu (__m128i, imm0_31);
__m128i __lsx_vmin_w (__m128i, __m128i);
__m128i __lsx_vmin_wu (__m128i, __m128i);
__m128i __lsx_vmod_b (__m128i, __m128i);
__m128i __lsx_vmod_bu (__m128i, __m128i);
__m128i __lsx_vmod_d (__m128i, __m128i);
__m128i __lsx_vmod_du (__m128i, __m128i);
__m128i __lsx_vmod_h (__m128i, __m128i);
__m128i __lsx_vmod_hu (__m128i, __m128i);
__m128i __lsx_vmod_w (__m128i, __m128i);
__m128i __lsx_vmod_wu (__m128i, __m128i);
__m128i __lsx_vmskgez_b (__m128i);
__m128i __lsx_vmskltz_b (__m128i);
__m128i __lsx_vmskltz_d (__m128i);
__m128i __lsx_vmskltz_h (__m128i);
__m128i __lsx_vmskltz_w (__m128i);
```

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__m128i __lsx_vmsknz_b (__m128i);
__m128i __lsx_vmsub_b (__m128i, __m128i, __m128i);
__m128i __lsx_vmsub_d (__m128i, __m128i, __m128i);
__m128i __lsx_vmsub_h (__m128i, __m128i, __m128i);
__m128i __lsx_vmsub_w (__m128i, __m128i, __m128i);
__m128i __lsx_vmuh_b (__m128i, __m128i);
__m128i __lsx_vmuh_bu (__m128i, __m128i);
__m128i __lsx_vmuh_d (__m128i, __m128i);
__m128i __lsx_vmuh_du (__m128i, __m128i);
__m128i __lsx_vmuh_h (__m128i, __m128i);
__m128i __lsx_vmuh_hu (__m128i, __m128i);
__m128i __lsx_vmuh_w (__m128i, __m128i);
__m128i __lsx_vmuh_wu (__m128i, __m128i);
__m128i __lsx_vmul_b (__m128i, __m128i);
__m128i __lsx_vmul_d (__m128i, __m128i);
__m128i __lsx_vmul_h (__m128i, __m128i);
__m128i __lsx_vmul_w (__m128i, __m128i);
__m128i __lsx_vmulwev_d_w (__m128i, __m128i);
__m128i __lsx_vmulwev_d_wu (__m128i, __m128i);
__m128i __lsx_vmulwev_d_wu_w (__m128i, __m128i);
__m128i __lsx_vmulwev_h_b (__m128i, __m128i);
__m128i __lsx_vmulwev_h_bu (__m128i, __m128i);
__m128i __lsx_vmulwev_h_bu_b (__m128i, __m128i);
__m128i __lsx_vmulwev_q_d (__m128i, __m128i);
__m128i __lsx_vmulwev_q_du (__m128i, __m128i);
__m128i __lsx_vmulwev_q_du_d (__m128i, __m128i);
__m128i __lsx_vmulwev_w_h (__m128i, __m128i);
__m128i __lsx_vmulwev_w_hu (__m128i, __m128i);
__m128i __lsx_vmulwev_w_hu_h (__m128i, __m128i);
__m128i __lsx_vmulwod_d_w (__m128i, __m128i);
__m128i __lsx_vmulwod_d_wu (__m128i, __m128i);
__m128i __lsx_vmulwod_d_wu_w (__m128i, __m128i);
__m128i __lsx_vmulwod_h_b (__m128i, __m128i);
__m128i __lsx_vmulwod_h_bu (__m128i, __m128i);
__m128i __lsx_vmulwod_h_bu_b (__m128i, __m128i);
__m128i __lsx_vmulwod_q_d (__m128i, __m128i);
__m128i __lsx_vmulwod_q_du (__m128i, __m128i);
__m128i __lsx_vmulwod_q_du_d (__m128i, __m128i);
__m128i __lsx_vmulwod_w_h (__m128i, __m128i);
__m128i __lsx_vmulwod_w_hu (__m128i, __m128i);
__m128i __lsx_vmulwod_w_hu_h (__m128i, __m128i);
__m128i __lsx_vneg_b (__m128i);
__m128i __lsx_vneg_d (__m128i);
__m128i __lsx_vneg_h (__m128i);
__m128i __lsx_vneg_w (__m128i);
__m128i __lsx_vnori_b (__m128i, imm0_255);
__m128i __lsx_vnor_v (__m128i, __m128i);
__m128i __lsx_vori_b (__m128i, imm0_255);
__m128i __lsx_vorn_v (__m128i, __m128i);
__m128i __lsx_vor_v (__m128i, __m128i);
__m128i __lsx_vpackev_b (__m128i, __m128i);
__m128i __lsx_vpackev_d (__m128i, __m128i);
__m128i __lsx_vpackev_h (__m128i, __m128i);
__m128i __lsx_vpackev_w (__m128i, __m128i);
__m128i __lsx_vpackod_b (__m128i, __m128i);
__m128i __lsx_vpackod_d (__m128i, __m128i);
__m128i __lsx_vpackod_h (__m128i, __m128i);
__m128i __lsx_vpackod_w (__m128i, __m128i);
```

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__m128i __lsx_vpcnt_b (__m128i);
__m128i __lsx_vpcnt_d (__m128i);
__m128i __lsx_vpcnt_h (__m128i);
__m128i __lsx_vpcnt_w (__m128i);
__m128i __lsx_vpermi_w (__m128i, __m128i, imm0_255);
__m128i __lsx_vpickev_b (__m128i, __m128i);
__m128i __lsx_vpickev_d (__m128i, __m128i);
__m128i __lsx_vpickev_h (__m128i, __m128i);
__m128i __lsx_vpickev_w (__m128i, __m128i);
__m128i __lsx_vpickod_b (__m128i, __m128i);
__m128i __lsx_vpickod_d (__m128i, __m128i);
__m128i __lsx_vpickod_h (__m128i, __m128i);
__m128i __lsx_vpickod_w (__m128i, __m128i);
int __lsx_vpickve2gr_b (__m128i, imm0_15);
unsigned int __lsx_vpickve2gr_bu (__m128i, imm0_15);
long int __lsx_vpickve2gr_d (__m128i, imm0_1);
unsigned long int __lsx_vpickve2gr_du (__m128i, imm0_1);
int __lsx_vpickve2gr_h (__m128i, imm0_7);
unsigned int __lsx_vpickve2gr_hu (__m128i, imm0_7);
int __lsx_vpickve2gr_w (__m128i, imm0_3);
unsigned int __lsx_vpickve2gr_wu (__m128i, imm0_3);
__m128i __lsx_vreplgr2vr_b (int);
__m128i __lsx_vreplgr2vr_d (long int);
__m128i __lsx_vreplgr2vr_h (int);
__m128i __lsx_vreplgr2vr_w (int);
__m128i __lsx_vrepli_b (imm_n512_511);
__m128i __lsx_vrepli_d (imm_n512_511);
__m128i __lsx_vrepli_h (imm_n512_511);
__m128i __lsx_vrepli_w (imm_n512_511);
__m128i __lsx_vreplve_b (__m128i, int);
__m128i __lsx_vreplve_d (__m128i, int);
__m128i __lsx_vreplve_h (__m128i, int);
__m128i __lsx_vreplvei_b (__m128i, imm0_15);
__m128i __lsx_vreplvei_d (__m128i, imm0_1);
__m128i __lsx_vreplvei_h (__m128i, imm0_7);
__m128i __lsx_vreplvei_w (__m128i, imm0_3);
__m128i __lsx_vreplve_w (__m128i, int);
__m128i __lsx_vrotr_b (__m128i, __m128i);
__m128i __lsx_vrotr_d (__m128i, __m128i);
__m128i __lsx_vrotr_h (__m128i, __m128i);
__m128i __lsx_vrotri_b (__m128i, imm0_7);
__m128i __lsx_vrotri_d (__m128i, imm0_63);
__m128i __lsx_vrotri_h (__m128i, imm0_15);
__m128i __lsx_vrotri_w (__m128i, imm0_31);
__m128i __lsx_vrotr_w (__m128i, __m128i);
__m128i __lsx_vsadd_b (__m128i, __m128i);
__m128i __lsx_vsadd_bu (__m128i, __m128i);
__m128i __lsx_vsadd_d (__m128i, __m128i);
__m128i __lsx_vsadd_du (__m128i, __m128i);
__m128i __lsx_vsadd_h (__m128i, __m128i);
__m128i __lsx_vsadd_hu (__m128i, __m128i);
__m128i __lsx_vsadd_w (__m128i, __m128i);
__m128i __lsx_vsadd_wu (__m128i, __m128i);
__m128i __lsx_vsat_b (__m128i, imm0_7);
__m128i __lsx_vsat_bu (__m128i, imm0_7);
__m128i __lsx_vsat_d (__m128i, imm0_63);
__m128i __lsx_vsat_du (__m128i, imm0_63);
__m128i __lsx_vsat_h (__m128i, imm0_15);
```

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__m128i __lsx_vsat_hu (__m128i, imm0_15);
__m128i __lsx_vsat_w (__m128i, imm0_31);
__m128i __lsx_vsat_wu (__m128i, imm0_31);
__m128i __lsx_vseq_b (__m128i, __m128i);
__m128i __lsx_vseq_d (__m128i, __m128i);
__m128i __lsx_vseq_h (__m128i, __m128i);
__m128i __lsx_vseqi_b (__m128i, imm_n16_15);
__m128i __lsx_vseqi_d (__m128i, imm_n16_15);
__m128i __lsx_vseqi_h (__m128i, imm_n16_15);
__m128i __lsx_vseqi_w (__m128i, imm_n16_15);
__m128i __lsx_vseq_w (__m128i, __m128i);
__m128i __lsx_vshuf4i_b (__m128i, imm0_255);
__m128i __lsx_vshuf4i_d (__m128i, __m128i, imm0_255);
__m128i __lsx_vshuf4i_h (__m128i, imm0_255);
__m128i __lsx_vshuf4i_w (__m128i, imm0_255);
__m128i __lsx_vshuf_b (__m128i, __m128i, __m128i);
__m128i __lsx_vshuf_d (__m128i, __m128i, __m128i);
__m128i __lsx_vshuf_h (__m128i, __m128i, __m128i);
__m128i __lsx_vshuf_w (__m128i, __m128i, __m128i);
__m128i __lsx_vsigncov_b (__m128i, __m128i);
__m128i __lsx_vsigncov_d (__m128i, __m128i);
__m128i __lsx_vsigncov_h (__m128i, __m128i);
__m128i __lsx_vsigncov_w (__m128i, __m128i);
__m128i __lsx_vsle_b (__m128i, __m128i);
__m128i __lsx_vsle_bu (__m128i, __m128i);
__m128i __lsx_vsle_d (__m128i, __m128i);
__m128i __lsx_vsle_du (__m128i, __m128i);
__m128i __lsx_vsle_h (__m128i, __m128i);
__m128i __lsx_vsle_hu (__m128i, __m128i);
__m128i __lsx_vslei_b (__m128i, imm_n16_15);
__m128i __lsx_vslei_bu (__m128i, imm0_31);
__m128i __lsx_vslei_d (__m128i, imm_n16_15);
__m128i __lsx_vslei_du (__m128i, imm0_31);
__m128i __lsx_vslei_h (__m128i, imm_n16_15);
__m128i __lsx_vslei_hu (__m128i, imm0_31);
__m128i __lsx_vslei_w (__m128i, imm_n16_15);
__m128i __lsx_vslei_wu (__m128i, imm0_31);
__m128i __lsx_vsle_w (__m128i, __m128i);
__m128i __lsx_vsle_wu (__m128i, __m128i);
__m128i __lsx_vsll_b (__m128i, __m128i);
__m128i __lsx_vsll_d (__m128i, __m128i);
__m128i __lsx_vsll_h (__m128i, __m128i);
__m128i __lsx_vslli_b (__m128i, imm0_7);
__m128i __lsx_vslli_d (__m128i, imm0_63);
__m128i __lsx_vslli_h (__m128i, imm0_15);
__m128i __lsx_vslli_w (__m128i, imm0_31);
__m128i __lsx_vsll_w (__m128i, __m128i);
__m128i __lsx_vsllwil_du_wu (__m128i, imm0_31);
__m128i __lsx_vsllwil_d_w (__m128i, imm0_31);
__m128i __lsx_vsllwil_h_b (__m128i, imm0_7);
__m128i __lsx_vsllwil_hu_bu (__m128i, imm0_7);
__m128i __lsx_vsllwil_w_h (__m128i, imm0_15);
__m128i __lsx_vsllwil_wu_hu (__m128i, imm0_15);
__m128i __lsx_vslt_b (__m128i, __m128i);
__m128i __lsx_vslt_bu (__m128i, __m128i);
__m128i __lsx_vslt_d (__m128i, __m128i);
__m128i __lsx_vslt_du (__m128i, __m128i);
__m128i __lsx_vslt_h (__m128i, __m128i);
```

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__m128i __lsx_vslt_hu (__m128i, __m128i);
__m128i __lsx_vslti_b (__m128i, imm_n16_15);
__m128i __lsx_vslti_bu (__m128i, imm0_31);
__m128i __lsx_vslti_d (__m128i, imm_n16_15);
__m128i __lsx_vslti_du (__m128i, imm0_31);
__m128i __lsx_vslti_h (__m128i, imm_n16_15);
__m128i __lsx_vslti_hu (__m128i, imm0_31);
__m128i __lsx_vslti_w (__m128i, imm_n16_15);
__m128i __lsx_vslti_wu (__m128i, imm0_31);
__m128i __lsx_vslt_w (__m128i, __m128i);
__m128i __lsx_vslt_wu (__m128i, __m128i);
__m128i __lsx_vsra_b (__m128i, __m128i);
__m128i __lsx_vsra_d (__m128i, __m128i);
__m128i __lsx_vsra_h (__m128i, __m128i);
__m128i __lsx_vsrai_b (__m128i, imm0_7);
__m128i __lsx_vsrai_d (__m128i, imm0_63);
__m128i __lsx_vsrai_h (__m128i, imm0_15);
__m128i __lsx_vsrai_w (__m128i, imm0_31);
__m128i __lsx_vsran_b_h (__m128i, __m128i);
__m128i __lsx_vsran_h_w (__m128i, __m128i);
__m128i __lsx_vsrani_b_h (__m128i, __m128i, imm0_15);
__m128i __lsx_vsrani_d_q (__m128i, __m128i, imm0_127);
__m128i __lsx_vsrani_h_w (__m128i, __m128i, imm0_31);
__m128i __lsx_vsrani_w_d (__m128i, __m128i, imm0_63);
__m128i __lsx_vsran_w_d (__m128i, __m128i);
__m128i __lsx_vsrar_b (__m128i, __m128i);
__m128i __lsx_vsrar_d (__m128i, __m128i);
__m128i __lsx_vsrar_h (__m128i, __m128i);
__m128i __lsx_vsrari_b (__m128i, imm0_7);
__m128i __lsx_vsrari_d (__m128i, imm0_63);
__m128i __lsx_vsrari_h (__m128i, imm0_15);
__m128i __lsx_vsrari_w (__m128i, imm0_31);
__m128i __lsx_vsrarn_b_h (__m128i, __m128i);
__m128i __lsx_vsrarn_h_w (__m128i, __m128i);
__m128i __lsx_vsrarni_b_h (__m128i, __m128i, imm0_15);
__m128i __lsx_vsrarni_d_q (__m128i, __m128i, imm0_127);
__m128i __lsx_vsrarni_h_w (__m128i, __m128i, imm0_31);
__m128i __lsx_vsrarni_w_d (__m128i, __m128i, imm0_63);
__m128i __lsx_vsrarn_w_d (__m128i, __m128i);
__m128i __lsx_vsrar_w (__m128i, __m128i);
__m128i __lsx_vsra_w (__m128i, __m128i);
__m128i __lsx_vsrl_b (__m128i, __m128i);
__m128i __lsx_vsrl_d (__m128i, __m128i);
__m128i __lsx_vsrl_h (__m128i, __m128i);
__m128i __lsx_vsrli_b (__m128i, imm0_7);
__m128i __lsx_vsrli_d (__m128i, imm0_63);
__m128i __lsx_vsrli_h (__m128i, imm0_15);
__m128i __lsx_vsrli_w (__m128i, imm0_31);
__m128i __lsx_vsrln_b_h (__m128i, __m128i);
__m128i __lsx_vsrln_h_w (__m128i, __m128i);
__m128i __lsx_vsrlni_b_h (__m128i, __m128i, imm0_15);
__m128i __lsx_vsrlni_d_q (__m128i, __m128i, imm0_127);
__m128i __lsx_vsrlni_h_w (__m128i, __m128i, imm0_31);
__m128i __lsx_vsrlni_w_d (__m128i, __m128i, imm0_63);
__m128i __lsx_vsrln_w_d (__m128i, __m128i);
__m128i __lsx_vsrlr_b (__m128i, __m128i);
__m128i __lsx_vsrlr_d (__m128i, __m128i);
__m128i __lsx_vsrlr_h (__m128i, __m128i);
```

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__m128i __lsx_vsrlri_b (__m128i, imm0_7);
__m128i __lsx_vsrlri_d (__m128i, imm0_63);
__m128i __lsx_vsrlri_h (__m128i, imm0_15);
__m128i __lsx_vsrlri_w (__m128i, imm0_31);
__m128i __lsx_vsrlrn_b_h (__m128i, __m128i);
__m128i __lsx_vsrlrn_h_w (__m128i, __m128i);
__m128i __lsx_vsrlrni_b_h (__m128i, __m128i, imm0_15);
__m128i __lsx_vsrlrni_d_q (__m128i, __m128i, imm0_127);
__m128i __lsx_vsrlrni_h_w (__m128i, __m128i, imm0_31);
__m128i __lsx_vsrlrni_w_d (__m128i, __m128i, imm0_63);
__m128i __lsx_vsrlrn_w_d (__m128i, __m128i);
__m128i __lsx_vsrlr_w (__m128i, __m128i);
__m128i __lsx_vsrl_w (__m128i, __m128i);
__m128i __lsx_vssran_b_h (__m128i, __m128i);
__m128i __lsx_vssran_bu_h (__m128i, __m128i);
__m128i __lsx_vssran_hu_w (__m128i, __m128i);
__m128i __lsx_vssran_h_w (__m128i, __m128i);
__m128i __lsx_vssrani_b_h (__m128i, __m128i, imm0_15);
__m128i __lsx_vssrani_bu_h (__m128i, __m128i, imm0_15);
__m128i __lsx_vssrani_d_q (__m128i, __m128i, imm0_127);
__m128i __lsx_vssrani_du_q (__m128i, __m128i, imm0_127);
__m128i __lsx_vssrani_hu_w (__m128i, __m128i, imm0_31);
__m128i __lsx_vssrani_h_w (__m128i, __m128i, imm0_31);
__m128i __lsx_vssrani_w_d (__m128i, __m128i, imm0_63);
__m128i __lsx_vssrani_wu_d (__m128i, __m128i, imm0_63);
__m128i __lsx_vssran_w_d (__m128i, __m128i);
__m128i __lsx_vssran_wu_d (__m128i, __m128i);
__m128i __lsx_vssrarn_b_h (__m128i, __m128i);
__m128i __lsx_vssrarn_bu_h (__m128i, __m128i);
__m128i __lsx_vssrarn_hu_w (__m128i, __m128i);
__m128i __lsx_vssrarn_h_w (__m128i, __m128i);
__m128i __lsx_vssrarni_b_h (__m128i, __m128i, imm0_15);
__m128i __lsx_vssrarni_bu_h (__m128i, __m128i, imm0_15);
__m128i __lsx_vssrarni_d_q (__m128i, __m128i, imm0_127);
__m128i __lsx_vssrarni_du_q (__m128i, __m128i, imm0_127);
__m128i __lsx_vssrarni_hu_w (__m128i, __m128i, imm0_31);
__m128i __lsx_vssrarni_h_w (__m128i, __m128i, imm0_31);
__m128i __lsx_vssrarni_w_d (__m128i, __m128i, imm0_63);
__m128i __lsx_vssrarni_wu_d (__m128i, __m128i, imm0_63);
__m128i __lsx_vssrarn_w_d (__m128i, __m128i);
__m128i __lsx_vssrarn_wu_d (__m128i, __m128i);
__m128i __lsx_vssrln_b_h (__m128i, __m128i);
__m128i __lsx_vssrln_bu_h (__m128i, __m128i);
__m128i __lsx_vssrln_hu_w (__m128i, __m128i);
__m128i __lsx_vssrln_h_w (__m128i, __m128i);
__m128i __lsx_vssrlni_b_h (__m128i, __m128i, imm0_15);
__m128i __lsx_vssrlni_bu_h (__m128i, __m128i, imm0_15);
__m128i __lsx_vssrlni_d_q (__m128i, __m128i, imm0_127);
__m128i __lsx_vssrlni_du_q (__m128i, __m128i, imm0_127);
__m128i __lsx_vssrlni_hu_w (__m128i, __m128i, imm0_31);
__m128i __lsx_vssrlni_h_w (__m128i, __m128i, imm0_31);
__m128i __lsx_vssrlni_w_d (__m128i, __m128i, imm0_63);
__m128i __lsx_vssrlni_wu_d (__m128i, __m128i, imm0_63);
__m128i __lsx_vssrln_w_d (__m128i, __m128i);
__m128i __lsx_vssrln_wu_d (__m128i, __m128i);
__m128i __lsx_vssrlrn_b_h (__m128i, __m128i);
__m128i __lsx_vssrlrn_bu_h (__m128i, __m128i);
__m128i __lsx_vssrlrn_hu_w (__m128i, __m128i);
```

```
__m128i __lsx_vssrlrn_h_w (__m128i, __m128i);
__m128i __lsx_vssrlrni_b_h (__m128i, __m128i, imm0_15);
__m128i __lsx_vssrlrni_bu_h (__m128i, __m128i, imm0_15);
__m128i __lsx_vssrlrni_d_q (__m128i, __m128i, imm0_127);
__m128i __lsx_vssrlrni_du_q (__m128i, __m128i, imm0_127);
__m128i __lsx_vssrlrni_hu_w (__m128i, __m128i, imm0_31);
__m128i __lsx_vssrlrni_h_w (__m128i, __m128i, imm0_31);
__m128i __lsx_vssrlrni_w_d (__m128i, __m128i, imm0_63);
__m128i __lsx_vssrlrni_wu_d (__m128i, __m128i, imm0_63);
__m128i __lsx_vssrlrn_w_d (__m128i, __m128i);
__m128i __lsx_vssrlrn_wu_d (__m128i, __m128i);
__m128i __lsx_vssub_b (__m128i, __m128i);
__m128i __lsx_vssub_bu (__m128i, __m128i);
__m128i __lsx_vssub_d (__m128i, __m128i);
__m128i __lsx_vssub_du (__m128i, __m128i);
__m128i __lsx_vssub_h (__m128i, __m128i);
__m128i __lsx_vssub_hu (__m128i, __m128i);
__m128i __lsx_vssub_w (__m128i, __m128i);
__m128i __lsx_vssub_wu (__m128i, __m128i);
void __lsx_vst (__m128i, void *, imm_n2048_2047);
void __lsx_vstelm_b (__m128i, void *, imm_n128_127, imm0_15);
void __lsx_vstelm_d (__m128i, void *, imm_n128_127, imm0_1);
void __lsx_vstelm_h (__m128i, void *, imm_n128_127, imm0_7);
void __lsx_vstelm_w (__m128i, void *, imm_n128_127, imm0_3);
void __lsx_vstx (__m128i, void *, long int);
__m128i __lsx_vsub_b (__m128i, __m128i);
__m128i __lsx_vsub_d (__m128i, __m128i);
__m128i __lsx_vsub_h (__m128i, __m128i);
__m128i __lsx_vsubi_bu (__m128i, imm0_31);
__m128i __lsx_vsubi_du (__m128i, imm0_31);
__m128i __lsx_vsubi_hu (__m128i, imm0_31);
__m128i __lsx_vsubi_wu (__m128i, imm0_31);
__m128i __lsx_vsub_q (__m128i, __m128i);
__m128i __lsx_vsub_w (__m128i, __m128i);
__m128i __lsx_vsubwev_d_w (__m128i, __m128i);
__m128i __lsx_vsubwev_d_wu (__m128i, __m128i);
__m128i __lsx_vsubwev_h_b (__m128i, __m128i);
__m128i __lsx_vsubwev_h_bu (__m128i, __m128i);
__m128i __lsx_vsubwev_q_d (__m128i, __m128i);
__m128i __lsx_vsubwev_q_du (__m128i, __m128i);
__m128i __lsx_vsubwev_w_h (__m128i, __m128i);
__m128i __lsx_vsubwev_w_hu (__m128i, __m128i);
__m128i __lsx_vsubwod_d_w (__m128i, __m128i);
__m128i __lsx_vsubwod_d_wu (__m128i, __m128i);
__m128i __lsx_vsubwod_h_b (__m128i, __m128i);
__m128i __lsx_vsubwod_h_bu (__m128i, __m128i);
__m128i __lsx_vsubwod_q_d (__m128i, __m128i);
__m128i __lsx_vsubwod_q_du (__m128i, __m128i);
__m128i __lsx_vsubwod_w_h (__m128i, __m128i);
__m128i __lsx_vsubwod_w_hu (__m128i, __m128i);
__m128i __lsx_vxori_b (__m128i, imm0_255);
__m128i __lsx_vxor_v (__m128i, __m128i);
```

7.13.13.3 Directly-mapped SX Division Builtin Functions

These intrinsic functions are available by including `lsxintrin.h` and using `-mfrecipe` and `-mlsx`.

```
__m128d __lsx_vfrecipe_d (__m128d);
```

```
__m128 __lsx_vfrecipe_s (__m128);
__m128d __lsx_vfrsqrte_d (__m128d);
__m128 __lsx_vfrsqrte_s (__m128);
```

7.13.14 LoongArch ASX Vector Intrinsics

GCC provides intrinsics to access the LASX (Loongson Advanced SIMD Extension) instructions. The interface is made available by including `<lasxintrin.h>` and using `-mlasx`.

7.13.14.1 ASX Data Types

The following vectors typedefs are included in `lasxintrin.h`:

- `__m256i`, a 256-bit vector of fixed point;
- `__m256`, a 256-bit vector of single precision floating point;
- `__m256d`, a 256-bit vector of double precision floating point.

Instructions and corresponding built-ins may have additional restrictions and/or input/output values manipulated:

- `imm0_1`, an integer literal in range 0 to 1.
- `imm0_3`, an integer literal in range 0 to 3.
- `imm0_7`, an integer literal in range 0 to 7.
- `imm0_15`, an integer literal in range 0 to 15.
- `imm0_31`, an integer literal in range 0 to 31.
- `imm0_63`, an integer literal in range 0 to 63.
- `imm0_127`, an integer literal in range 0 to 127.
- `imm0_255`, an integer literal in range 0 to 255.
- `imm_n16_15`, an integer literal in range -16 to 15.
- `imm_n128_127`, an integer literal in range -128 to 127.
- `imm_n256_255`, an integer literal in range -256 to 255.
- `imm_n512_511`, an integer literal in range -512 to 511.
- `imm_n1024_1023`, an integer literal in range -1024 to 1023.
- `imm_n2048_2047`, an integer literal in range -2048 to 2047.

7.13.14.2 Directly-mapped ASX Builtin Functions

For convenience, GCC defines functions `__lasx_xvrepli_{b/h/w/d}` and `__lasx_b[n]z_{v/b/h/w/d}`, which are implemented as follows:

```
a. __lasx_xvrepli_{b/h/w/d}: Implemented the case where the highest
   bit of xvldi instruction i13 is 1.

   i13[12] == 1'b0
   case i13[11:10] of :
     2'b00: __lasx_xvrepli_b (imm_n512_511)
     2'b01: __lasx_xvrepli_h (imm_n512_511)
     2'b10: __lasx_xvrepli_w (imm_n512_511)
     2'b11: __lasx_xvrepli_d (imm_n512_511)

b. __lasx_b[n]z_{v/b/h/w/d}: Since the xvseteqz class directive
   cannot be used on its own, this function is defined.
```

```
 __lasx_xbz_v  => xvseteqz.v + bcnez
 __lasx_xbnz_v => xvsetnez.v + bcnez
 __lasx_xbz_b  => xvsetanyeqz.b + bcnez
 __lasx_xbz_h  => xvsetanyeqz.h + bcnez
 __lasx_xbz_w  => xvsetanyeqz.w + bcnez
 __lasx_xbz_d  => xvsetanyeqz.d + bcnez
 __lasx_xbnz_b => xvsetallnez.b + bcnez
 __lasx_xbnz_h => xvsetallnez.h + bcnez
 __lasx_xbnz_w => xvsetallnez.w + bcnez
 __lasx_xbnz_d => xvsetallnez.d + bcnez
```

```
eg:
  #include <lasxintrin.h>

  extern __m256i a;

  void
  test (void)
  {
    if (__lasx_xbz_v (a))
      printf ("1\n");
    else
      printf ("2\n");
  }
```

Note: For directives where the intent operand is also the source operand (modifying only part of the bitfield of the intent register), the first parameter in the builtin call function is used as the intent operand.

```
eg:
  #include <lasxintrin.h>
  extern __m256i dst;
  int src;

  void
  test (void)
  {
    dst = __lasx_xvinsgr2vr_w (dst, src, 3);
  }
```

The intrinsics provided are listed below:

```
__m256i __lasx_vext2xv_d_b (__m256i);
__m256i __lasx_vext2xv_d_h (__m256i);
__m256i __lasx_vext2xv_du_bu (__m256i);
__m256i __lasx_vext2xv_du_hu (__m256i);
__m256i __lasx_vext2xv_du_wu (__m256i);
__m256i __lasx_vext2xv_d_w (__m256i);
__m256i __lasx_vext2xv_h_b (__m256i);
__m256i __lasx_vext2xv_hu_bu (__m256i);
__m256i __lasx_vext2xv_w_b (__m256i);
__m256i __lasx_vext2xv_w_h (__m256i);
__m256i __lasx_vext2xv_wu_bu (__m256i);
__m256i __lasx_vext2xv_wu_hu (__m256i);
int __lasx_xbnz_b (__m256i);
int __lasx_xbnz_d (__m256i);
int __lasx_xbnz_h (__m256i);
int __lasx_xbnz_v (__m256i);
int __lasx_xbnz_w (__m256i);
int __lasx_xbz_b (__m256i);
```

```
int __lasx_xbz_d (__m256i);
int __lasx_xbz_h (__m256i);
int __lasx_xbz_v (__m256i);
int __lasx_xbz_w (__m256i);
__m256i __lasx_xvabsd_b (__m256i, __m256i);
__m256i __lasx_xvabsd_bu (__m256i, __m256i);
__m256i __lasx_xvabsd_d (__m256i, __m256i);
__m256i __lasx_xvabsd_du (__m256i, __m256i);
__m256i __lasx_xvabsd_h (__m256i, __m256i);
__m256i __lasx_xvabsd_hu (__m256i, __m256i);
__m256i __lasx_xvabsd_w (__m256i, __m256i);
__m256i __lasx_xvabsd_wu (__m256i, __m256i);
__m256i __lasx_xvadda_b (__m256i, __m256i);
__m256i __lasx_xvadda_d (__m256i, __m256i);
__m256i __lasx_xvadda_h (__m256i, __m256i);
__m256i __lasx_xvadda_w (__m256i, __m256i);
__m256i __lasx_xvadd_b (__m256i, __m256i);
__m256i __lasx_xvadd_d (__m256i, __m256i);
__m256i __lasx_xvadd_h (__m256i, __m256i);
__m256i __lasx_xvaddi_bu (__m256i, imm0_31);
__m256i __lasx_xvaddi_du (__m256i, imm0_31);
__m256i __lasx_xvaddi_hu (__m256i, imm0_31);
__m256i __lasx_xvaddi_wu (__m256i, imm0_31);
__m256i __lasx_xvadd_q (__m256i, __m256i);
__m256i __lasx_xvadd_w (__m256i, __m256i);
__m256i __lasx_xvaddwev_d_w (__m256i, __m256i);
__m256i __lasx_xvaddwev_d_wu (__m256i, __m256i);
__m256i __lasx_xvaddwev_d_wu_w (__m256i, __m256i);
__m256i __lasx_xvaddwev_h_b (__m256i, __m256i);
__m256i __lasx_xvaddwev_h_bu (__m256i, __m256i);
__m256i __lasx_xvaddwev_h_bu_b (__m256i, __m256i);
__m256i __lasx_xvaddwev_q_d (__m256i, __m256i);
__m256i __lasx_xvaddwev_q_du (__m256i, __m256i);
__m256i __lasx_xvaddwev_q_du_d (__m256i, __m256i);
__m256i __lasx_xvaddwev_w_h (__m256i, __m256i);
__m256i __lasx_xvaddwev_w_hu (__m256i, __m256i);
__m256i __lasx_xvaddwev_w_hu_h (__m256i, __m256i);
__m256i __lasx_xvaddwod_d_w (__m256i, __m256i);
__m256i __lasx_xvaddwod_d_wu (__m256i, __m256i);
__m256i __lasx_xvaddwod_d_wu_w (__m256i, __m256i);
__m256i __lasx_xvaddwod_h_b (__m256i, __m256i);
__m256i __lasx_xvaddwod_h_bu (__m256i, __m256i);
__m256i __lasx_xvaddwod_h_bu_b (__m256i, __m256i);
__m256i __lasx_xvaddwod_q_d (__m256i, __m256i);
__m256i __lasx_xvaddwod_q_du (__m256i, __m256i);
__m256i __lasx_xvaddwod_q_du_d (__m256i, __m256i);
__m256i __lasx_xvaddwod_w_h (__m256i, __m256i);
__m256i __lasx_xvaddwod_w_hu (__m256i, __m256i);
__m256i __lasx_xvaddwod_w_hu_h (__m256i, __m256i);
__m256i __lasx_xvandi_b (__m256i, imm0_255);
__m256i __lasx_xvandn_v (__m256i, __m256i);
__m256i __lasx_xvand_v (__m256i, __m256i);
__m256i __lasx_xvavg_b (__m256i, __m256i);
__m256i __lasx_xvavg_bu (__m256i, __m256i);
__m256i __lasx_xvavg_d (__m256i, __m256i);
__m256i __lasx_xvavg_du (__m256i, __m256i);
__m256i __lasx_xvavg_h (__m256i, __m256i);
__m256i __lasx_xvavg_hu (__m256i, __m256i);
```

```
__m256i __lasx_xvavgr_b (__m256i, __m256i);
__m256i __lasx_xvavgr_bu (__m256i, __m256i);
__m256i __lasx_xvavgr_d (__m256i, __m256i);
__m256i __lasx_xvavgr_du (__m256i, __m256i);
__m256i __lasx_xvavgr_h (__m256i, __m256i);
__m256i __lasx_xvavgr_hu (__m256i, __m256i);
__m256i __lasx_xvavgr_w (__m256i, __m256i);
__m256i __lasx_xvavgr_wu (__m256i, __m256i);
__m256i __lasx_xvavg_w (__m256i, __m256i);
__m256i __lasx_xvavg_wu (__m256i, __m256i);
__m256i __lasx_xvbitclr_b (__m256i, __m256i);
__m256i __lasx_xvbitclr_d (__m256i, __m256i);
__m256i __lasx_xvbitclr_h (__m256i, __m256i);
__m256i __lasx_xvbitclri_b (__m256i, imm0_7);
__m256i __lasx_xvbitclri_d (__m256i, imm0_63);
__m256i __lasx_xvbitclri_h (__m256i, imm0_15);
__m256i __lasx_xvbitclri_w (__m256i, imm0_31);
__m256i __lasx_xvbitclr_w (__m256i, __m256i);
__m256i __lasx_xvbitrev_b (__m256i, __m256i);
__m256i __lasx_xvbitrev_d (__m256i, __m256i);
__m256i __lasx_xvbitrev_h (__m256i, __m256i);
__m256i __lasx_xvbitrevi_b (__m256i, imm0_7);
__m256i __lasx_xvbitrevi_d (__m256i, imm0_63);
__m256i __lasx_xvbitrevi_h (__m256i, imm0_15);
__m256i __lasx_xvbitrevi_w (__m256i, imm0_31);
__m256i __lasx_xvbitrev_w (__m256i, __m256i);
__m256i __lasx_xvbitseli_b (__m256i, __m256i, imm0_255);
__m256i __lasx_xvbitsel_v (__m256i, __m256i, __m256i);
__m256i __lasx_xvbitset_b (__m256i, __m256i);
__m256i __lasx_xvbitset_d (__m256i, __m256i);
__m256i __lasx_xvbitset_h (__m256i, __m256i);
__m256i __lasx_xvbitseti_b (__m256i, imm0_7);
__m256i __lasx_xvbitseti_d (__m256i, imm0_63);
__m256i __lasx_xvbitseti_h (__m256i, imm0_15);
__m256i __lasx_xvbitseti_w (__m256i, imm0_31);
__m256i __lasx_xvbitset_w (__m256i, __m256i);
__m256i __lasx_xvbsll_v (__m256i, imm0_31);
__m256i __lasx_xvbsrl_v (__m256i, imm0_31);
__m256i __lasx_xvclo_b (__m256i);
__m256i __lasx_xvclo_d (__m256i);
__m256i __lasx_xvclo_h (__m256i);
__m256i __lasx_xvclo_w (__m256i);
__m256i __lasx_xvclz_b (__m256i);
__m256i __lasx_xvclz_d (__m256i);
__m256i __lasx_xvclz_h (__m256i);
__m256i __lasx_xvclz_w (__m256i);
__m256i __lasx_xvdiv_b (__m256i, __m256i);
__m256i __lasx_xvdiv_bu (__m256i, __m256i);
__m256i __lasx_xvdiv_d (__m256i, __m256i);
__m256i __lasx_xvdiv_du (__m256i, __m256i);
__m256i __lasx_xvdiv_h (__m256i, __m256i);
__m256i __lasx_xvdiv_hu (__m256i, __m256i);
__m256i __lasx_xvdiv_w (__m256i, __m256i);
__m256i __lasx_xvdiv_wu (__m256i, __m256i);
__m256i __lasx_xvexth_du_wu (__m256i);
__m256i __lasx_xvexth_d_w (__m256i);
__m256i __lasx_xvexth_h_b (__m256i);
__m256i __lasx_xvexth_hu_bu (__m256i);
```

```
__m256i __lasx_xvexth_q_d (__m256i);
__m256i __lasx_xvexth_qu_du (__m256i);
__m256i __lasx_xvexth_w_h (__m256i);
__m256i __lasx_xvexth_wu_hu (__m256i);
__m256i __lasx_xvextl_q_d (__m256i);
__m256i __lasx_xvextl_qu_du (__m256i);
__m256i __lasx_xvextrins_b (__m256i, __m256i, imm0_255);
__m256i __lasx_xvextrins_d (__m256i, __m256i, imm0_255);
__m256i __lasx_xvextrins_h (__m256i, __m256i, imm0_255);
__m256i __lasx_xvextrins_w (__m256i, __m256i, imm0_255);
__m256d __lasx_xvfadd_d (__m256d, __m256d);
__m256 __lasx_xvfadd_s (__m256, __m256);
__m256i __lasx_xvfclass_d (__m256d);
__m256i __lasx_xvfclass_s (__m256);
__m256i __lasx_xvfcmp_caf_d (__m256d, __m256d);
__m256i __lasx_xvfcmp_caf_s (__m256, __m256);
__m256i __lasx_xvfcmp_ceq_d (__m256d, __m256d);
__m256i __lasx_xvfcmp_ceq_s (__m256, __m256);
__m256i __lasx_xvfcmp_cle_d (__m256d, __m256d);
__m256i __lasx_xvfcmp_cle_s (__m256, __m256);
__m256i __lasx_xvfcmp_clt_d (__m256d, __m256d);
__m256i __lasx_xvfcmp_clt_s (__m256, __m256);
__m256i __lasx_xvfcmp_cne_d (__m256d, __m256d);
__m256i __lasx_xvfcmp_cne_s (__m256, __m256);
__m256i __lasx_xvfcmp_cor_d (__m256d, __m256d);
__m256i __lasx_xvfcmp_cor_s (__m256, __m256);
__m256i __lasx_xvfcmp_cueq_d (__m256d, __m256d);
__m256i __lasx_xvfcmp_cueq_s (__m256, __m256);
__m256i __lasx_xvfcmp_cule_d (__m256d, __m256d);
__m256i __lasx_xvfcmp_cule_s (__m256, __m256);
__m256i __lasx_xvfcmp_cult_d (__m256d, __m256d);
__m256i __lasx_xvfcmp_cult_s (__m256, __m256);
__m256i __lasx_xvfcmp_cun_d (__m256d, __m256d);
__m256i __lasx_xvfcmp_cune_d (__m256d, __m256d);
__m256i __lasx_xvfcmp_cune_s (__m256, __m256);
__m256i __lasx_xvfcmp_cun_s (__m256, __m256);
__m256i __lasx_xvfcmp_saf_d (__m256d, __m256d);
__m256i __lasx_xvfcmp_saf_s (__m256, __m256);
__m256i __lasx_xvfcmp_seq_d (__m256d, __m256d);
__m256i __lasx_xvfcmp_seq_s (__m256, __m256);
__m256i __lasx_xvfcmp_sle_d (__m256d, __m256d);
__m256i __lasx_xvfcmp_sle_s (__m256, __m256);
__m256i __lasx_xvfcmp_slt_d (__m256d, __m256d);
__m256i __lasx_xvfcmp_slt_s (__m256, __m256);
__m256i __lasx_xvfcmp_sne_d (__m256d, __m256d);
__m256i __lasx_xvfcmp_sne_s (__m256, __m256);
__m256i __lasx_xvfcmp_sor_d (__m256d, __m256d);
__m256i __lasx_xvfcmp_sor_s (__m256, __m256);
__m256i __lasx_xvfcmp_sueq_d (__m256d, __m256d);
__m256i __lasx_xvfcmp_sueq_s (__m256, __m256);
__m256i __lasx_xvfcmp_sule_d (__m256d, __m256d);
__m256i __lasx_xvfcmp_sule_s (__m256, __m256);
__m256i __lasx_xvfcmp_sult_d (__m256d, __m256d);
__m256i __lasx_xvfcmp_sult_s (__m256, __m256);
__m256i __lasx_xvfcmp_sun_d (__m256d, __m256d);
__m256i __lasx_xvfcmp_sune_d (__m256d, __m256d);
__m256i __lasx_xvfcmp_sune_s (__m256, __m256);
__m256i __lasx_xvfcmp_sun_s (__m256, __m256);
```

```
__m256d __lasx_xvfcvth_d_s (__m256);
__m256i __lasx_xvfcvt_h_s (__m256, __m256);
__m256 __lasx_xvfcvth_s_h (__m256i);
__m256d __lasx_xvfcvtl_d_s (__m256);
__m256 __lasx_xvfcvtl_s_h (__m256i);
__m256 __lasx_xvfcvt_s_d (__m256d, __m256d);
__m256d __lasx_xvfdiv_d (__m256d, __m256d);
__m256 __lasx_xvfdiv_s (__m256, __m256);
__m256d __lasx_xvffint_d_l (__m256i);
__m256d __lasx_xvffint_d_lu (__m256i);
__m256d __lasx_xvffinth_d_w (__m256i);
__m256d __lasx_xvffintl_d_w (__m256i);
__m256 __lasx_xvffint_s_l (__m256i, __m256i);
__m256 __lasx_xvffint_s_w (__m256i);
__m256 __lasx_xvffint_s_wu (__m256i);
__m256d __lasx_xvflogb_d (__m256d);
__m256 __lasx_xvflogb_s (__m256);
__m256d __lasx_xvfmadd_d (__m256d, __m256d, __m256d);
__m256 __lasx_xvfmadd_s (__m256, __m256, __m256);
__m256d __lasx_xvfmaxa_d (__m256d, __m256d);
__m256 __lasx_xvfmaxa_s (__m256, __m256);
__m256d __lasx_xvfmax_d (__m256d, __m256d);
__m256 __lasx_xvfmax_s (__m256, __m256);
__m256d __lasx_xvfmina_d (__m256d, __m256d);
__m256 __lasx_xvfmina_s (__m256, __m256);
__m256d __lasx_xvfmin_d (__m256d, __m256d);
__m256 __lasx_xvfmin_s (__m256, __m256);
__m256d __lasx_xvfmsub_d (__m256d, __m256d, __m256d);
__m256 __lasx_xvfmsub_s (__m256, __m256, __m256);
__m256d __lasx_xvfmul_d (__m256d, __m256d);
__m256 __lasx_xvfmul_s (__m256, __m256);
__m256d __lasx_xvfnmadd_d (__m256d, __m256d, __m256d);
__m256 __lasx_xvfnmadd_s (__m256, __m256, __m256);
__m256d __lasx_xvfnmsub_d (__m256d, __m256d, __m256d);
__m256 __lasx_xvfnmsub_s (__m256, __m256, __m256);
__m256d __lasx_xvfrecip_d (__m256d);
__m256 __lasx_xvfrecip_s (__m256);
__m256d __lasx_xvfrint_d (__m256d);
__m256d __lasx_xvfrintrm_d (__m256d);
__m256 __lasx_xvfrintrm_s (__m256);
__m256d __lasx_xvfrintrne_d (__m256d);
__m256 __lasx_xvfrintrne_s (__m256);
__m256d __lasx_xvfrintrp_d (__m256d);
__m256 __lasx_xvfrintrp_s (__m256);
__m256d __lasx_xvfrintrz_d (__m256d);
__m256 __lasx_xvfrintrz_s (__m256);
__m256 __lasx_xvfrint_s (__m256);
__m256d __lasx_xvfrsqrt_d (__m256d);
__m256 __lasx_xvfrsqrt_s (__m256);
__m256i __lasx_xvfrstp_b (__m256i, __m256i, __m256i);
__m256i __lasx_xvfrstp_h (__m256i, __m256i, __m256i);
__m256i __lasx_xvfrstpi_b (__m256i, __m256i, imm0_31);
__m256i __lasx_xvfrstpi_h (__m256i, __m256i, imm0_31);
__m256d __lasx_xvfsqrt_d (__m256d);
__m256 __lasx_xvfsqrt_s (__m256);
__m256d __lasx_xvfsub_d (__m256d, __m256d);
__m256 __lasx_xvfsub_s (__m256, __m256);
__m256i __lasx_xvftinth_l_s (__m256);
```

```
__m256i __lasx_xvftint_l_d (__m256d);
__m256i __lasx_xvftintl_l_s (__m256);
__m256i __lasx_xvftint_lu_d (__m256d);
__m256i __lasx_xvftintrmh_l_s (__m256);
__m256i __lasx_xvftintrm_l_d (__m256d);
__m256i __lasx_xvftintrml_l_s (__m256);
__m256i __lasx_xvftintrm_w_d (__m256d, __m256d);
__m256i __lasx_xvftintrm_w_s (__m256);
__m256i __lasx_xvftintrneh_l_s (__m256);
__m256i __lasx_xvftintrne_l_d (__m256d);
__m256i __lasx_xvftintrnel_l_s (__m256);
__m256i __lasx_xvftintrne_w_d (__m256d, __m256d);
__m256i __lasx_xvftintrne_w_s (__m256);
__m256i __lasx_xvftintrph_l_s (__m256);
__m256i __lasx_xvftintrp_l_d (__m256d);
__m256i __lasx_xvftintrpl_l_s (__m256);
__m256i __lasx_xvftintrp_w_d (__m256d, __m256d);
__m256i __lasx_xvftintrp_w_s (__m256);
__m256i __lasx_xvftintrzh_l_s (__m256);
__m256i __lasx_xvftintrz_l_d (__m256d);
__m256i __lasx_xvftintrzl_l_s (__m256);
__m256i __lasx_xvftintrz_lu_d (__m256d);
__m256i __lasx_xvftintrz_w_d (__m256d, __m256d);
__m256i __lasx_xvftintrz_w_s (__m256);
__m256i __lasx_xvftintrz_wu_s (__m256);
__m256i __lasx_xvftint_w_d (__m256d, __m256d);
__m256i __lasx_xvftint_w_s (__m256);
__m256i __lasx_xvftint_wu_s (__m256);
__m256i __lasx_xvhaddw_du_wu (__m256i, __m256i);
__m256i __lasx_xvhaddw_d_w (__m256i, __m256i);
__m256i __lasx_xvhaddw_h_b (__m256i, __m256i);
__m256i __lasx_xvhaddw_hu_bu (__m256i, __m256i);
__m256i __lasx_xvhaddw_q_d (__m256i, __m256i);
__m256i __lasx_xvhaddw_qu_du (__m256i, __m256i);
__m256i __lasx_xvhaddw_w_h (__m256i, __m256i);
__m256i __lasx_xvhaddw_wu_hu (__m256i, __m256i);
__m256i __lasx_xvhsubw_du_wu (__m256i, __m256i);
__m256i __lasx_xvhsubw_d_w (__m256i, __m256i);
__m256i __lasx_xvhsubw_h_b (__m256i, __m256i);
__m256i __lasx_xvhsubw_hu_bu (__m256i, __m256i);
__m256i __lasx_xvhsubw_q_d (__m256i, __m256i);
__m256i __lasx_xvhsubw_qu_du (__m256i, __m256i);
__m256i __lasx_xvhsubw_w_h (__m256i, __m256i);
__m256i __lasx_xvhsubw_wu_hu (__m256i, __m256i);
__m256i __lasx_xvilvh_b (__m256i, __m256i);
__m256i __lasx_xvilvh_d (__m256i, __m256i);
__m256i __lasx_xvilvh_h (__m256i, __m256i);
__m256i __lasx_xvilvh_w (__m256i, __m256i);
__m256i __lasx_xvilvl_b (__m256i, __m256i);
__m256i __lasx_xvilvl_d (__m256i, __m256i);
__m256i __lasx_xvilvl_h (__m256i, __m256i);
__m256i __lasx_xvilvl_w (__m256i, __m256i);
__m256i __lasx_xvinsgr2vr_d (__m256i, long int, imm0_3);
__m256i __lasx_xvinsgr2vr_w (__m256i, int, imm0_7);
__m256i __lasx_xvinsve0_d (__m256i, __m256i, imm0_3);
__m256i __lasx_xvinsve0_w (__m256i, __m256i, imm0_7);
__m256i __lasx_xvld (void *, imm_n2048_2047);
__m256i __lasx_xvldi (imm_n1024_1023);
```

```
__m256i __lasx_xvldrepl_b (void *, imm_n2048_2047);
__m256i __lasx_xvldrepl_d (void *, imm_n256_255);
__m256i __lasx_xvldrepl_h (void *, imm_n1024_1023);
__m256i __lasx_xvldrepl_w (void *, imm_n512_511);
__m256i __lasx_xvldx (void *, long int);
__m256i __lasx_xvmadd_b (__m256i, __m256i, __m256i);
__m256i __lasx_xvmadd_d (__m256i, __m256i, __m256i);
__m256i __lasx_xvmadd_h (__m256i, __m256i, __m256i);
__m256i __lasx_xvmadd_w (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwev_d_w (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwev_d_wu (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwev_d_wu_w (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwev_h_b (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwev_h_bu (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwev_h_bu_b (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwev_q_d (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwev_q_du (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwev_q_du_d (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwev_w_h (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwev_w_hu (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwev_w_hu_h (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwod_d_w (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwod_d_wu (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwod_d_wu_w (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwod_h_b (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwod_h_bu (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwod_h_bu_b (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwod_q_d (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwod_q_du (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwod_q_du_d (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwod_w_h (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwod_w_hu (__m256i, __m256i, __m256i);
__m256i __lasx_xvmaddwod_w_hu_h (__m256i, __m256i, __m256i);
__m256i __lasx_xvmax_b (__m256i, __m256i);
__m256i __lasx_xvmax_bu (__m256i, __m256i);
__m256i __lasx_xvmax_d (__m256i, __m256i);
__m256i __lasx_xvmax_du (__m256i, __m256i);
__m256i __lasx_xvmax_h (__m256i, __m256i);
__m256i __lasx_xvmax_hu (__m256i, __m256i);
__m256i __lasx_xvmaxi_b (__m256i, imm_n16_15);
__m256i __lasx_xvmaxi_bu (__m256i, imm0_31);
__m256i __lasx_xvmaxi_d (__m256i, imm_n16_15);
__m256i __lasx_xvmaxi_du (__m256i, imm0_31);
__m256i __lasx_xvmaxi_h (__m256i, imm_n16_15);
__m256i __lasx_xvmaxi_hu (__m256i, imm0_31);
__m256i __lasx_xvmaxi_w (__m256i, imm_n16_15);
__m256i __lasx_xvmaxi_wu (__m256i, imm0_31);
__m256i __lasx_xvmax_w (__m256i, __m256i);
__m256i __lasx_xvmax_wu (__m256i, __m256i);
__m256i __lasx_xvmin_b (__m256i, __m256i);
__m256i __lasx_xvmin_bu (__m256i, __m256i);
__m256i __lasx_xvmin_d (__m256i, __m256i);
__m256i __lasx_xvmin_du (__m256i, __m256i);
__m256i __lasx_xvmin_h (__m256i, __m256i);
__m256i __lasx_xvmin_hu (__m256i, __m256i);
__m256i __lasx_xvmini_b (__m256i, imm_n16_15);
__m256i __lasx_xvmini_bu (__m256i, imm0_31);
__m256i __lasx_xvmini_d (__m256i, imm_n16_15);
```

```
__m256i __lasx_xvmini_du (__m256i, imm0_31);
__m256i __lasx_xvmini_h (__m256i, imm_n16_15);
__m256i __lasx_xvmini_hu (__m256i, imm0_31);
__m256i __lasx_xvmini_w (__m256i, imm_n16_15);
__m256i __lasx_xvmini_wu (__m256i, imm0_31);
__m256i __lasx_xvmin_w (__m256i, __m256i);
__m256i __lasx_xvmin_wu (__m256i, __m256i);
__m256i __lasx_xvmod_b (__m256i, __m256i);
__m256i __lasx_xvmod_bu (__m256i, __m256i);
__m256i __lasx_xvmod_d (__m256i, __m256i);
__m256i __lasx_xvmod_du (__m256i, __m256i);
__m256i __lasx_xvmod_h (__m256i, __m256i);
__m256i __lasx_xvmod_hu (__m256i, __m256i);
__m256i __lasx_xvmod_w (__m256i, __m256i);
__m256i __lasx_xvmod_wu (__m256i, __m256i);
__m256i __lasx_xvmskgez_b (__m256i);
__m256i __lasx_xvmskltz_b (__m256i);
__m256i __lasx_xvmskltz_d (__m256i);
__m256i __lasx_xvmskltz_h (__m256i);
__m256i __lasx_xvmskltz_w (__m256i);
__m256i __lasx_xvmsknz_b (__m256i);
__m256i __lasx_xvmsub_b (__m256i, __m256i, __m256i);
__m256i __lasx_xvmsub_d (__m256i, __m256i, __m256i);
__m256i __lasx_xvmsub_h (__m256i, __m256i, __m256i);
__m256i __lasx_xvmsub_w (__m256i, __m256i, __m256i);
__m256i __lasx_xvmuh_b (__m256i, __m256i);
__m256i __lasx_xvmuh_bu (__m256i, __m256i);
__m256i __lasx_xvmuh_d (__m256i, __m256i);
__m256i __lasx_xvmuh_du (__m256i, __m256i);
__m256i __lasx_xvmuh_h (__m256i, __m256i);
__m256i __lasx_xvmuh_hu (__m256i, __m256i);
__m256i __lasx_xvmuh_w (__m256i, __m256i);
__m256i __lasx_xvmuh_wu (__m256i, __m256i);
__m256i __lasx_xvmul_b (__m256i, __m256i);
__m256i __lasx_xvmul_d (__m256i, __m256i);
__m256i __lasx_xvmul_h (__m256i, __m256i);
__m256i __lasx_xvmul_w (__m256i, __m256i);
__m256i __lasx_xvmulwev_d_w (__m256i, __m256i);
__m256i __lasx_xvmulwev_d_wu (__m256i, __m256i);
__m256i __lasx_xvmulwev_d_wu_w (__m256i, __m256i);
__m256i __lasx_xvmulwev_h_b (__m256i, __m256i);
__m256i __lasx_xvmulwev_h_bu (__m256i, __m256i);
__m256i __lasx_xvmulwev_h_bu_b (__m256i, __m256i);
__m256i __lasx_xvmulwev_q_d (__m256i, __m256i);
__m256i __lasx_xvmulwev_q_du (__m256i, __m256i);
__m256i __lasx_xvmulwev_q_du_d (__m256i, __m256i);
__m256i __lasx_xvmulwev_w_h (__m256i, __m256i);
__m256i __lasx_xvmulwev_w_hu (__m256i, __m256i);
__m256i __lasx_xvmulwev_w_hu_h (__m256i, __m256i);
__m256i __lasx_xvmulwod_d_w (__m256i, __m256i);
__m256i __lasx_xvmulwod_d_wu (__m256i, __m256i);
__m256i __lasx_xvmulwod_d_wu_w (__m256i, __m256i);
__m256i __lasx_xvmulwod_h_b (__m256i, __m256i);
__m256i __lasx_xvmulwod_h_bu (__m256i, __m256i);
__m256i __lasx_xvmulwod_h_bu_b (__m256i, __m256i);
__m256i __lasx_xvmulwod_q_d (__m256i, __m256i);
__m256i __lasx_xvmulwod_q_du (__m256i, __m256i);
__m256i __lasx_xvmulwod_q_du_d (__m256i, __m256i);
```

```
__m256i __lasx_xvmulwod_w_h (__m256i, __m256i);
__m256i __lasx_xvmulwod_w_hu (__m256i, __m256i);
__m256i __lasx_xvmulwod_w_hu_h (__m256i, __m256i);
__m256i __lasx_xvneg_b (__m256i);
__m256i __lasx_xvneg_d (__m256i);
__m256i __lasx_xvneg_h (__m256i);
__m256i __lasx_xvneg_w (__m256i);
__m256i __lasx_xvnori_b (__m256i, imm0_255);
__m256i __lasx_xvnor_v (__m256i, __m256i);
__m256i __lasx_xvori_b (__m256i, imm0_255);
__m256i __lasx_xvorn_v (__m256i, __m256i);
__m256i __lasx_xvor_v (__m256i, __m256i);
__m256i __lasx_xvpackev_b (__m256i, __m256i);
__m256i __lasx_xvpackev_d (__m256i, __m256i);
__m256i __lasx_xvpackev_h (__m256i, __m256i);
__m256i __lasx_xvpackev_w (__m256i, __m256i);
__m256i __lasx_xvpackod_b (__m256i, __m256i);
__m256i __lasx_xvpackod_d (__m256i, __m256i);
__m256i __lasx_xvpackod_h (__m256i, __m256i);
__m256i __lasx_xvpackod_w (__m256i, __m256i);
__m256i __lasx_xvpcnt_b (__m256i);
__m256i __lasx_xvpcnt_d (__m256i);
__m256i __lasx_xvpcnt_h (__m256i);
__m256i __lasx_xvpcnt_w (__m256i);
__m256i __lasx_xvpermi_d (__m256i, imm0_255);
__m256i __lasx_xvpermi_q (__m256i, __m256i, imm0_255);
__m256i __lasx_xvpermi_w (__m256i, __m256i, imm0_255);
__m256i __lasx_xvperm_w (__m256i, __m256i);
__m256i __lasx_xvpickev_b (__m256i, __m256i);
__m256i __lasx_xvpickev_d (__m256i, __m256i);
__m256i __lasx_xvpickev_h (__m256i, __m256i);
__m256i __lasx_xvpickev_w (__m256i, __m256i);
__m256i __lasx_xvpickod_b (__m256i, __m256i);
__m256i __lasx_xvpickod_d (__m256i, __m256i);
__m256i __lasx_xvpickod_h (__m256i, __m256i);
__m256i __lasx_xvpickod_w (__m256i, __m256i);
long int __lasx_xvpickve2gr_d (__m256i, imm0_3);
unsigned long int __lasx_xvpickve2gr_du (__m256i, imm0_3);
int __lasx_xvpickve2gr_w (__m256i, imm0_7);
unsigned int __lasx_xvpickve2gr_wu (__m256i, imm0_7);
__m256i __lasx_xvpickve_d (__m256i, imm0_3);
__m256d __lasx_xvpickve_d_f (__m256d, imm0_3);
__m256i __lasx_xvpickve_w (__m256i, imm0_7);
__m256 __lasx_xvpickve_w_f (__m256, imm0_7);
__m256i __lasx_xvrepl128vei_b (__m256i, imm0_15);
__m256i __lasx_xvrepl128vei_d (__m256i, imm0_1);
__m256i __lasx_xvrepl128vei_h (__m256i, imm0_7);
__m256i __lasx_xvrepl128vei_w (__m256i, imm0_3);
__m256i __lasx_xvreplgr2vr_b (int);
__m256i __lasx_xvreplgr2vr_d (long int);
__m256i __lasx_xvreplgr2vr_h (int);
__m256i __lasx_xvreplgr2vr_w (int);
__m256i __lasx_xvrepli_b (imm_n512_511);
__m256i __lasx_xvrepli_d (imm_n512_511);
__m256i __lasx_xvrepli_h (imm_n512_511);
__m256i __lasx_xvrepli_w (imm_n512_511);
__m256i __lasx_xvreplve0_b (__m256i);
__m256i __lasx_xvreplve0_d (__m256i);
```

```
__m256i __lasx_xvreplve0_h (__m256i);
__m256i __lasx_xvreplve0_q (__m256i);
__m256i __lasx_xvreplve0_w (__m256i);
__m256i __lasx_xvreplve_b (__m256i, int);
__m256i __lasx_xvreplve_d (__m256i, int);
__m256i __lasx_xvreplve_h (__m256i, int);
__m256i __lasx_xvreplve_w (__m256i, int);
__m256i __lasx_xvrotr_b (__m256i, __m256i);
__m256i __lasx_xvrotr_d (__m256i, __m256i);
__m256i __lasx_xvrotr_h (__m256i, __m256i);
__m256i __lasx_xvrotri_b (__m256i, imm0_7);
__m256i __lasx_xvrotri_d (__m256i, imm0_63);
__m256i __lasx_xvrotri_h (__m256i, imm0_15);
__m256i __lasx_xvrotri_w (__m256i, imm0_31);
__m256i __lasx_xvrotr_w (__m256i, __m256i);
__m256i __lasx_xvsadd_b (__m256i, __m256i);
__m256i __lasx_xvsadd_bu (__m256i, __m256i);
__m256i __lasx_xvsadd_d (__m256i, __m256i);
__m256i __lasx_xvsadd_du (__m256i, __m256i);
__m256i __lasx_xvsadd_h (__m256i, __m256i);
__m256i __lasx_xvsadd_hu (__m256i, __m256i);
__m256i __lasx_xvsadd_w (__m256i, __m256i);
__m256i __lasx_xvsadd_wu (__m256i, __m256i);
__m256i __lasx_xvsat_b (__m256i, imm0_7);
__m256i __lasx_xvsat_bu (__m256i, imm0_7);
__m256i __lasx_xvsat_d (__m256i, imm0_63);
__m256i __lasx_xvsat_du (__m256i, imm0_63);
__m256i __lasx_xvsat_h (__m256i, imm0_15);
__m256i __lasx_xvsat_hu (__m256i, imm0_15);
__m256i __lasx_xvsat_w (__m256i, imm0_31);
__m256i __lasx_xvsat_wu (__m256i, imm0_31);
__m256i __lasx_xvseq_b (__m256i, __m256i);
__m256i __lasx_xvseq_d (__m256i, __m256i);
__m256i __lasx_xvseq_h (__m256i, __m256i);
__m256i __lasx_xvseqi_b (__m256i, imm_n16_15);
__m256i __lasx_xvseqi_d (__m256i, imm_n16_15);
__m256i __lasx_xvseqi_h (__m256i, imm_n16_15);
__m256i __lasx_xvseqi_w (__m256i, imm_n16_15);
__m256i __lasx_xvseq_w (__m256i, __m256i);
__m256i __lasx_xvshuf4i_b (__m256i, imm0_255);
__m256i __lasx_xvshuf4i_d (__m256i, __m256i, imm0_255);
__m256i __lasx_xvshuf4i_h (__m256i, imm0_255);
__m256i __lasx_xvshuf4i_w (__m256i, imm0_255);
__m256i __lasx_xvshuf_b (__m256i, __m256i, __m256i);
__m256i __lasx_xvshuf_d (__m256i, __m256i, __m256i);
__m256i __lasx_xvshuf_h (__m256i, __m256i, __m256i);
__m256i __lasx_xvshuf_w (__m256i, __m256i, __m256i);
__m256i __lasx_xvsigncov_b (__m256i, __m256i);
__m256i __lasx_xvsigncov_d (__m256i, __m256i);
__m256i __lasx_xvsigncov_h (__m256i, __m256i);
__m256i __lasx_xvsigncov_w (__m256i, __m256i);
__m256i __lasx_xvsle_b (__m256i, __m256i);
__m256i __lasx_xvsle_bu (__m256i, __m256i);
__m256i __lasx_xvsle_d (__m256i, __m256i);
__m256i __lasx_xvsle_du (__m256i, __m256i);
__m256i __lasx_xvsle_h (__m256i, __m256i);
__m256i __lasx_xvsle_hu (__m256i, __m256i);
__m256i __lasx_xvslei_b (__m256i, imm_n16_15);
```

```
__m256i __lasx_xvslei_bu (__m256i, imm0_31);
__m256i __lasx_xvslei_d (__m256i, imm_n16_15);
__m256i __lasx_xvslei_du (__m256i, imm0_31);
__m256i __lasx_xvslei_h (__m256i, imm_n16_15);
__m256i __lasx_xvslei_hu (__m256i, imm0_31);
__m256i __lasx_xvslei_w (__m256i, imm_n16_15);
__m256i __lasx_xvslei_wu (__m256i, imm0_31);
__m256i __lasx_xvsle_w (__m256i, __m256i);
__m256i __lasx_xvsle_wu (__m256i, __m256i);
__m256i __lasx_xvsll_b (__m256i, __m256i);
__m256i __lasx_xvsll_d (__m256i, __m256i);
__m256i __lasx_xvsll_h (__m256i, __m256i);
__m256i __lasx_xvslli_b (__m256i, imm0_7);
__m256i __lasx_xvslli_d (__m256i, imm0_63);
__m256i __lasx_xvslli_h (__m256i, imm0_15);
__m256i __lasx_xvslli_w (__m256i, imm0_31);
__m256i __lasx_xvsll_w (__m256i, __m256i);
__m256i __lasx_xvsllwil_du_wu (__m256i, imm0_31);
__m256i __lasx_xvsllwil_d_w (__m256i, imm0_31);
__m256i __lasx_xvsllwil_h_b (__m256i, imm0_7);
__m256i __lasx_xvsllwil_hu_bu (__m256i, imm0_7);
__m256i __lasx_xvsllwil_w_h (__m256i, imm0_15);
__m256i __lasx_xvsllwil_wu_hu (__m256i, imm0_15);
__m256i __lasx_xvslt_b (__m256i, __m256i);
__m256i __lasx_xvslt_bu (__m256i, __m256i);
__m256i __lasx_xvslt_d (__m256i, __m256i);
__m256i __lasx_xvslt_du (__m256i, __m256i);
__m256i __lasx_xvslt_h (__m256i, __m256i);
__m256i __lasx_xvslt_hu (__m256i, __m256i);
__m256i __lasx_xvslti_b (__m256i, imm_n16_15);
__m256i __lasx_xvslti_bu (__m256i, imm0_31);
__m256i __lasx_xvslti_d (__m256i, imm_n16_15);
__m256i __lasx_xvslti_du (__m256i, imm0_31);
__m256i __lasx_xvslti_h (__m256i, imm_n16_15);
__m256i __lasx_xvslti_hu (__m256i, imm0_31);
__m256i __lasx_xvslti_w (__m256i, imm_n16_15);
__m256i __lasx_xvslti_wu (__m256i, imm0_31);
__m256i __lasx_xvslt_w (__m256i, __m256i);
__m256i __lasx_xvslt_wu (__m256i, __m256i);
__m256i __lasx_xvsra_b (__m256i, __m256i);
__m256i __lasx_xvsra_d (__m256i, __m256i);
__m256i __lasx_xvsra_h (__m256i, __m256i);
__m256i __lasx_xvsrai_b (__m256i, imm0_7);
__m256i __lasx_xvsrai_d (__m256i, imm0_63);
__m256i __lasx_xvsrai_h (__m256i, imm0_15);
__m256i __lasx_xvsrai_w (__m256i, imm0_31);
__m256i __lasx_xvsran_b_h (__m256i, __m256i);
__m256i __lasx_xvsran_h_w (__m256i, __m256i);
__m256i __lasx_xvsrani_b_h (__m256i, __m256i, imm0_15);
__m256i __lasx_xvsrani_d_q (__m256i, __m256i, imm0_127);
__m256i __lasx_xvsrani_h_w (__m256i, __m256i, imm0_31);
__m256i __lasx_xvsrani_w_d (__m256i, __m256i, imm0_63);
__m256i __lasx_xvsran_w_d (__m256i, __m256i);
__m256i __lasx_xvsrar_b (__m256i, __m256i);
__m256i __lasx_xvsrar_d (__m256i, __m256i);
__m256i __lasx_xvsrar_h (__m256i, __m256i);
__m256i __lasx_xvsrari_b (__m256i, imm0_7);
__m256i __lasx_xvsrari_d (__m256i, imm0_63);
```

```
__m256i __lasx_xvsrari_h (__m256i, imm0_15);
__m256i __lasx_xvsrari_w (__m256i, imm0_31);
__m256i __lasx_xvsrarn_b_h (__m256i, __m256i);
__m256i __lasx_xvsrarn_h_w (__m256i, __m256i);
__m256i __lasx_xvsrarni_b_h (__m256i, __m256i, imm0_15);
__m256i __lasx_xvsrarni_d_q (__m256i, __m256i, imm0_127);
__m256i __lasx_xvsrarni_h_w (__m256i, __m256i, imm0_31);
__m256i __lasx_xvsrarni_w_d (__m256i, __m256i, imm0_63);
__m256i __lasx_xvsrarn_w_d (__m256i, __m256i);
__m256i __lasx_xvsrar_w (__m256i, __m256i);
__m256i __lasx_xvsra_w (__m256i, __m256i);
__m256i __lasx_xvsrl_b (__m256i, __m256i);
__m256i __lasx_xvsrl_d (__m256i, __m256i);
__m256i __lasx_xvsrl_h (__m256i, __m256i);
__m256i __lasx_xvsrli_b (__m256i, imm0_7);
__m256i __lasx_xvsrli_d (__m256i, imm0_63);
__m256i __lasx_xvsrli_h (__m256i, imm0_15);
__m256i __lasx_xvsrli_w (__m256i, imm0_31);
__m256i __lasx_xvsrln_b_h (__m256i, __m256i);
__m256i __lasx_xvsrln_h_w (__m256i, __m256i);
__m256i __lasx_xvsrlni_b_h (__m256i, __m256i, imm0_15);
__m256i __lasx_xvsrlni_d_q (__m256i, __m256i, imm0_127);
__m256i __lasx_xvsrlni_h_w (__m256i, __m256i, imm0_31);
__m256i __lasx_xvsrlni_w_d (__m256i, __m256i, imm0_63);
__m256i __lasx_xvsrln_w_d (__m256i, __m256i);
__m256i __lasx_xvsrlr_b (__m256i, __m256i);
__m256i __lasx_xvsrlr_d (__m256i, __m256i);
__m256i __lasx_xvsrlr_h (__m256i, __m256i);
__m256i __lasx_xvsrlri_b (__m256i, imm0_7);
__m256i __lasx_xvsrlri_d (__m256i, imm0_63);
__m256i __lasx_xvsrlri_h (__m256i, imm0_15);
__m256i __lasx_xvsrlri_w (__m256i, imm0_31);
__m256i __lasx_xvsrlrn_b_h (__m256i, __m256i);
__m256i __lasx_xvsrlrn_h_w (__m256i, __m256i);
__m256i __lasx_xvsrlrni_b_h (__m256i, __m256i, imm0_15);
__m256i __lasx_xvsrlrni_d_q (__m256i, __m256i, imm0_127);
__m256i __lasx_xvsrlrni_h_w (__m256i, __m256i, imm0_31);
__m256i __lasx_xvsrlrni_w_d (__m256i, __m256i, imm0_63);
__m256i __lasx_xvsrlrn_w_d (__m256i, __m256i);
__m256i __lasx_xvsrlr_w (__m256i, __m256i);
__m256i __lasx_xvsrl_w (__m256i, __m256i);
__m256i __lasx_xvssran_b_h (__m256i, __m256i);
__m256i __lasx_xvssran_bu_h (__m256i, __m256i);
__m256i __lasx_xvssran_hu_w (__m256i, __m256i);
__m256i __lasx_xvssran_h_w (__m256i, __m256i);
__m256i __lasx_xvssrani_b_h (__m256i, __m256i, imm0_15);
__m256i __lasx_xvssrani_bu_h (__m256i, __m256i, imm0_15);
__m256i __lasx_xvssrani_d_q (__m256i, __m256i, imm0_127);
__m256i __lasx_xvssrani_du_q (__m256i, __m256i, imm0_127);
__m256i __lasx_xvssrani_hu_w (__m256i, __m256i, imm0_31);
__m256i __lasx_xvssrani_h_w (__m256i, __m256i, imm0_31);
__m256i __lasx_xvssrani_w_d (__m256i, __m256i, imm0_63);
__m256i __lasx_xvssrani_wu_d (__m256i, __m256i, imm0_63);
__m256i __lasx_xvssran_w_d (__m256i, __m256i);
__m256i __lasx_xvssran_wu_d (__m256i, __m256i);
__m256i __lasx_xvssrarn_b_h (__m256i, __m256i);
__m256i __lasx_xvssrarn_bu_h (__m256i, __m256i);
__m256i __lasx_xvssrarn_hu_w (__m256i, __m256i);
```

```
__m256i __lasx_xvssrarn_h_w (__m256i, __m256i);
__m256i __lasx_xvssrarni_b_h (__m256i, __m256i, imm0_15);
__m256i __lasx_xvssrarni_bu_h (__m256i, __m256i, imm0_15);
__m256i __lasx_xvssrarni_d_q (__m256i, __m256i, imm0_127);
__m256i __lasx_xvssrarni_du_q (__m256i, __m256i, imm0_127);
__m256i __lasx_xvssrarni_hu_w (__m256i, __m256i, imm0_31);
__m256i __lasx_xvssrarni_h_w (__m256i, __m256i, imm0_31);
__m256i __lasx_xvssrarni_w_d (__m256i, __m256i, imm0_63);
__m256i __lasx_xvssrarni_wu_d (__m256i, __m256i, imm0_63);
__m256i __lasx_xvssrarn_w_d (__m256i, __m256i);
__m256i __lasx_xvssrarn_wu_d (__m256i, __m256i);
__m256i __lasx_xvssrln_b_h (__m256i, __m256i);
__m256i __lasx_xvssrln_bu_h (__m256i, __m256i);
__m256i __lasx_xvssrln_hu_w (__m256i, __m256i);
__m256i __lasx_xvssrln_h_w (__m256i, __m256i);
__m256i __lasx_xvssrlni_b_h (__m256i, __m256i, imm0_15);
__m256i __lasx_xvssrlni_bu_h (__m256i, __m256i, imm0_15);
__m256i __lasx_xvssrlni_d_q (__m256i, __m256i, imm0_127);
__m256i __lasx_xvssrlni_du_q (__m256i, __m256i, imm0_127);
__m256i __lasx_xvssrlni_hu_w (__m256i, __m256i, imm0_31);
__m256i __lasx_xvssrlni_h_w (__m256i, __m256i, imm0_31);
__m256i __lasx_xvssrlni_w_d (__m256i, __m256i, imm0_63);
__m256i __lasx_xvssrlni_wu_d (__m256i, __m256i, imm0_63);
__m256i __lasx_xvssrln_w_d (__m256i, __m256i);
__m256i __lasx_xvssrln_wu_d (__m256i, __m256i);
__m256i __lasx_xvssrlrn_b_h (__m256i, __m256i);
__m256i __lasx_xvssrlrn_bu_h (__m256i, __m256i);
__m256i __lasx_xvssrlrn_hu_w (__m256i, __m256i);
__m256i __lasx_xvssrlrn_h_w (__m256i, __m256i);
__m256i __lasx_xvssrlrni_b_h (__m256i, __m256i, imm0_15);
__m256i __lasx_xvssrlrni_bu_h (__m256i, __m256i, imm0_15);
__m256i __lasx_xvssrlrni_d_q (__m256i, __m256i, imm0_127);
__m256i __lasx_xvssrlrni_du_q (__m256i, __m256i, imm0_127);
__m256i __lasx_xvssrlrni_hu_w (__m256i, __m256i, imm0_31);
__m256i __lasx_xvssrlrni_h_w (__m256i, __m256i, imm0_31);
__m256i __lasx_xvssrlrni_w_d (__m256i, __m256i, imm0_63);
__m256i __lasx_xvssrlrni_wu_d (__m256i, __m256i, imm0_63);
__m256i __lasx_xvssrlrn_w_d (__m256i, __m256i);
__m256i __lasx_xvssrlrn_wu_d (__m256i, __m256i);
__m256i __lasx_xvssub_b (__m256i, __m256i);
__m256i __lasx_xvssub_bu (__m256i, __m256i);
__m256i __lasx_xvssub_d (__m256i, __m256i);
__m256i __lasx_xvssub_du (__m256i, __m256i);
__m256i __lasx_xvssub_h (__m256i, __m256i);
__m256i __lasx_xvssub_hu (__m256i, __m256i);
__m256i __lasx_xvssub_w (__m256i, __m256i);
__m256i __lasx_xvssub_wu (__m256i, __m256i);
void __lasx_xvst (__m256i, void *, imm_n2048_2047);
void __lasx_xvstelm_b (__m256i, void *, imm_n128_127, imm0_31);
void __lasx_xvstelm_d (__m256i, void *, imm_n128_127, imm0_3);
void __lasx_xvstelm_h (__m256i, void *, imm_n128_127, imm0_15);
void __lasx_xvstelm_w (__m256i, void *, imm_n128_127, imm0_7);
void __lasx_xvstx (__m256i, void *, long int);
__m256i __lasx_xvsub_b (__m256i, __m256i);
__m256i __lasx_xvsub_d (__m256i, __m256i);
__m256i __lasx_xvsub_h (__m256i, __m256i);
__m256i __lasx_xvsubi_bu (__m256i, imm0_31);
__m256i __lasx_xvsubi_du (__m256i, imm0_31);
```

```
__m256i __lasx_xvsubi_hu (__m256i, imm0_31);
__m256i __lasx_xvsubi_wu (__m256i, imm0_31);
__m256i __lasx_xvsub_q (__m256i, __m256i);
__m256i __lasx_xvsub_w (__m256i, __m256i);
__m256i __lasx_xvsubwev_d_w (__m256i, __m256i);
__m256i __lasx_xvsubwev_d_wu (__m256i, __m256i);
__m256i __lasx_xvsubwev_h_b (__m256i, __m256i);
__m256i __lasx_xvsubwev_h_bu (__m256i, __m256i);
__m256i __lasx_xvsubwev_q_d (__m256i, __m256i);
__m256i __lasx_xvsubwev_q_du (__m256i, __m256i);
__m256i __lasx_xvsubwev_w_h (__m256i, __m256i);
__m256i __lasx_xvsubwev_w_hu (__m256i, __m256i);
__m256i __lasx_xvsubwod_d_w (__m256i, __m256i);
__m256i __lasx_xvsubwod_d_wu (__m256i, __m256i);
__m256i __lasx_xvsubwod_h_b (__m256i, __m256i);
__m256i __lasx_xvsubwod_h_bu (__m256i, __m256i);
__m256i __lasx_xvsubwod_q_d (__m256i, __m256i);
__m256i __lasx_xvsubwod_q_du (__m256i, __m256i);
__m256i __lasx_xvsubwod_w_h (__m256i, __m256i);
__m256i __lasx_xvsubwod_w_hu (__m256i, __m256i);
__m256i __lasx_xvxori_b (__m256i, imm0_255);
__m256i __lasx_xvxor_v (__m256i, __m256i);
```

7.13.14.3 Directly-mapped ASX Division Builtin Functions

These intrinsic functions are available by including `lasxintrin.h` and using `-mfrecipe` and `-mlasx`.

```
__m256d __lasx_xvfrecipe_d (__m256d);
__m256 __lasx_xvfrecipe_s (__m256);
__m256d __lasx_xvfrsqrte_d (__m256d);
__m256 __lasx_xvfrsqrte_s (__m256);
```

7.13.14.4 Directly-mapped SX and ASX Conversion Builtin Functions

For convenience, the `lsxintrin.h` file was imported into `lasxintrin.h` and 18 new interface functions for 128 and 256 vector conversions were added, using the `-mlasx` option.

```
__m256 __lasx_cast_128_s (__m128);
__m256d __lasx_cast_128_d (__m128d);
__m256i __lasx_cast_128 (__m128i);
__m256 __lasx_concat_128_s (__m128, __m128);
__m256d __lasx_concat_128_d (__m128d, __m128d);
__m256i __lasx_concat_128 (__m128i, __m128i);
__m128 __lasx_extract_128_lo_s (__m256);
__m128 __lasx_extract_128_hi_s (__m256);
__m128d __lasx_extract_128_lo_d (__m256d);
__m128d __lasx_extract_128_hi_d (__m256d);
__m128i __lasx_extract_128_lo (__m256i);
__m128i __lasx_extract_128_hi (__m256i);
__m256 __lasx_insert_128_lo_s (__m256, __m128);
__m256 __lasx_insert_128_hi_s (__m256, __m128);
__m256d __lasx_insert_128_lo_d (__m256d, __m128d);
__m256d __lasx_insert_128_hi_d (__m256d, __m128d);
__m256i __lasx_insert_128_lo (__m256i, __m128i);
__m256i __lasx_insert_128_hi (__m256i, __m128i);
```

When gcc does not support interfaces for 128 and 256 conversions, use the following code for equivalent substitution.

```
#ifndef __loongarch_asx_sx_conv

#include <lasxintrin.h>
#include <lsxintrin.h>
__m256 inline __attribute__((__gnu_inline__, __always_inline__, __artificial__))
__lasx_cast_128_s (__m128 src)
{
  __m256 dest;
  asm ("" : "=f"(dest) : "0"(src));
  return dest;
}

__m256d inline __attribute__((__gnu_inline__, __always_inline__, __artificial__))
__lasx_cast_128_d (__m128d src)
{
  __m256d dest;
  asm ("" : "=f"(dest) : "0"(src));
  return dest;
}

__m256i inline __attribute__((__gnu_inline__, __always_inline__, __artificial__))
__lasx_cast_128 (__m128i src)
{
  __m256i dest;
  asm ("" : "=f"(dest) : "0"(src));
  return dest;
}

__m256 inline __attribute__((__gnu_inline__, __always_inline__, __artificial__))
__lasx_concat_128_s (__m128 src1, __m128 src2)
{
  __m256 dest;
  asm ("xvpermi.q %u0,%u2,0x02\n"
        : "=f"(dest)
        : "0"(src1), "f"(src2));
  return dest;
}

__m256d inline __attribute__((__gnu_inline__, __always_inline__, __artificial__))
__lasx_concat_128_d (__m128d src1, __m128d src2)
{
  __m256d dest;
  asm ("xvpermi.q %u0,%u2,0x02\n"
        : "=f"(dest)
        : "0"(src1), "f"(src2));
  return dest;
}

__m256i inline __attribute__((__gnu_inline__, __always_inline__, __artificial__))
__lasx_concat_128 (__m128i src1, __m128i src2)
{
  __m256i dest;
  asm ("xvpermi.q %u0,%u2,0x02\n"
        : "=f"(dest)
        : "0"(src1), "f"(src2));
  return dest;
}
```

```
__m128 inline __attribute__((__gnu_inline__, __always_inline__, __artificial__))
__lasx_extract_128_lo_s (__m256 src)
{
  __m128 dest;
  asm ("" : "=f"(dest) : "0"(src));
  return dest;
}

__m128d inline __attribute__((__gnu_inline__, __always_inline__, __artificial__))
__lasx_extract_128_lo_d (__m256d src)
{
  __m128d dest;
  asm ("" : "=f"(dest) : "0"(src));
  return dest;
}

__m128i inline __attribute__((__gnu_inline__, __always_inline__, __artificial__))
__lasx_extract_128_lo (__m256i src)
{
  __m128i dest;
  asm ("" : "=f"(dest) : "0"(src));
  return dest;
}

__m128 inline __attribute__((__gnu_inline__, __always_inline__, __artificial__))
__lasx_extract_128_hi_s (__m256 src)
{
  __m128 dest;
  asm ("xvpermi.d %u0,%u1,0xe\n"
       : "=f"(dest)
       : "f"(src));
  return dest;
}

__m128d inline __attribute__((__gnu_inline__, __always_inline__, __artificial__))
__lasx_extract_128_hi_d (__m256d src)
{
  __m128d dest;
  asm ("xvpermi.d %u0,%u1,0xe\n"
       : "=f"(dest)
       : "f"(src));
  return dest;
}

__m128i inline __attribute__((__gnu_inline__, __always_inline__, __artificial__))
__lasx_extract_128_hi (__m256i src)
{
  __m128i dest;
  asm ("xvpermi.d %u0,%u1,0xe\n"
       : "=f"(dest)
       : "f"(src));
  return dest;
}

__m256 inline __attribute__((__gnu_inline__, __always_inline__, __artificial__))
__lasx_insert_128_lo_s (__m256 src1, __m128 src2)
{
```

```
  __m256 dest;
  asm ("xvpermi.q %u0,%u2,0x30\n"
        : "=f"(dest)
        : "0"(src1), "f"(src2));
  return dest;
}

__m256d inline __attribute__((__gnu_inline__, __always_inline__, __artificial__))
__lasx_insert_128_lo_d (__m256d a, __m128d b)
{
  __m256d dest;
  asm ("xvpermi.q %u0,%u2,0x30\n"
        : "=f"(dest)
        : "0"(src1), "f"(src2));
  return dest;
}

__m256i inline __attribute__((__gnu_inline__, __always_inline__, __artificial__))
__lasx_insert_128_lo (__m256i src1, __m128i src2)
{
  __m256i dest;
  asm ("xvpermi.q %u0,%u2,0x30\n"
        : "=f"(dest)
        : "0"(src1), "f"(src2));
  return dest;
}

__m256 inline __attribute__((__gnu_inline__, __always_inline__, __artificial__))
__lasx_insert_128_hi_s (__m256 src1, __m128 src2)
{
  __m256 dest;
  asm ("xvpermi.q %u0,%u2,0x02\n"
        : "=f"(dest)
        : "0"(src1), "f"(src2));
  return dest;
}

__m256d inline __attribute__((__gnu_inline__, __always_inline__, __artificial__))
__lasx_insert_128_hi_d (__m256d src1, __m128d src2)
{
  __m256d dest;
  asm ("xvpermi.q %u0,%u2,0x02\n"
        : "=f"(dest)
        : "0"(src1), "f"(src2));
  return dest;
}

__m256i inline __attribute__((__gnu_inline__, __always_inline__, __artificial__))
__lasx_insert_128_hi (__m256i src1, __m128i src2)
{
  __m256i dest;
  asm ("xvpermi.q %u0,%u2,0x02\n"
        : "=f"(dest)
        : "0"(src1), "f"(src2));
  return dest;
}
#endif
```

7.13.15 MIPS DSP Built-in Functions

The MIPS DSP Application-Specific Extension (ASE) includes new instructions that are designed to improve the performance of DSP and media applications. It provides instructions that operate on packed 8-bit/16-bit integer data, Q7, Q15 and Q31 fractional data.

GCC supports MIPS DSP operations using both the generic vector extensions (see Section 7.8 [Vector Extensions], page 850) and a collection of MIPS-specific built-in functions. Both kinds of support are enabled by the `-mdsp` command-line option.

Revision 2 of the ASE was introduced in the second half of 2006. This revision adds extra instructions to the original ASE, but is otherwise backwards-compatible with it. You can select revision 2 using the command-line option `-mdspr2`; this option implies `-mdsp`.

The SCOUNT and POS bits of the DSP control register are global. The WRDSP, EXTPDP, EXTPDPV and MTHLIP instructions modify the SCOUNT and POS bits. During optimization, the compiler does not delete these instructions and it does not delete calls to functions containing these instructions.

At present, GCC only provides support for operations on 32-bit vectors. The vector type associated with 8-bit integer data is usually called `v4i8`, the vector type associated with Q7 is usually called `v4q7`, the vector type associated with 16-bit integer data is usually called `v2i16`, and the vector type associated with Q15 is usually called `v2q15`. They can be defined in C as follows:

```
typedef signed char v4i8 __attribute__ ((vector_size(4)));
typedef signed char v4q7 __attribute__ ((vector_size(4)));
typedef short v2i16 __attribute__ ((vector_size(4)));
typedef short v2q15 __attribute__ ((vector_size(4)));
```

`v4i8`, `v4q7`, `v2i16` and `v2q15` values are initialized in the same way as aggregates. For example:

```
v4i8 a = {1, 2, 3, 4};
v4i8 b;
b = (v4i8) {5, 6, 7, 8};

v2q15 c = {0x0fcb, 0x3a75};
v2q15 d;
d = (v2q15) {0.1234 * 0x1.0p15, 0.4567 * 0x1.0p15};
```

Note: The CPU's endianness determines the order in which values are packed. On little-endian targets, the first value is the least significant and the last value is the most significant. The opposite order applies to big-endian targets. For example, the code above sets the lowest byte of `a` to `1` on little-endian targets and `4` on big-endian targets.

Note: Q7, Q15 and Q31 values must be initialized with their integer representation. As shown in this example, the integer representation of a Q7 value can be obtained by multiplying the fractional value by `0x1.0p7`. The equivalent for Q15 values is to multiply by `0x1.0p15`. The equivalent for Q31 values is to multiply by `0x1.0p31`.

The table below lists the `v4i8` and `v2q15` operations for which hardware support exists. `a` and `b` are `v4i8` values, and `c` and `d` are `v2q15` values.

C code	MIPS instruction
`a + b`	`addu.qb`
`c + d`	`addq.ph`
`a - b`	`subu.qb`

`c - d`	`subq.ph`

The table below lists the `v2i16` operation for which hardware support exists for the DSP ASE REV 2. `e` and `f` are `v2i16` values.

C code	**MIPS instruction**
`e * f`	`mul.ph`

It is easier to describe the DSP built-in functions if we first define the following types:

```
typedef int q31;
typedef int i32;
typedef unsigned int ui32;
typedef long long a64;
```

`q31` and `i32` are actually the same as `int`, but we use `q31` to indicate a Q31 fractional value and `i32` to indicate a 32-bit integer value. Similarly, `a64` is the same as `long long`, but we use `a64` to indicate values that are placed in one of the four DSP accumulators (`$ac0`, `$ac1`, `$ac2` or `$ac3`).

Also, some built-in functions prefer or require immediate numbers as parameters, because the corresponding DSP instructions accept both immediate numbers and register operands, or accept immediate numbers only. The immediate parameters are listed as follows.

```
imm0_3: 0 to 3.
imm0_7: 0 to 7.
imm0_15: 0 to 15.
imm0_31: 0 to 31.
imm0_63: 0 to 63.
imm0_255: 0 to 255.
imm_n32_31: -32 to 31.
imm_n512_511: -512 to 511.
```

The following built-in functions map directly to a particular MIPS DSP instruction. Please refer to the architecture specification for details on what each instruction does.

```
v2q15 __builtin_mips_addq_ph (v2q15, v2q15);
v2q15 __builtin_mips_addq_s_ph (v2q15, v2q15);
q31 __builtin_mips_addq_s_w (q31, q31);
v4i8 __builtin_mips_addu_qb (v4i8, v4i8);
v4i8 __builtin_mips_addu_s_qb (v4i8, v4i8);
v2q15 __builtin_mips_subq_ph (v2q15, v2q15);
v2q15 __builtin_mips_subq_s_ph (v2q15, v2q15);
q31 __builtin_mips_subq_s_w (q31, q31);
v4i8 __builtin_mips_subu_qb (v4i8, v4i8);
v4i8 __builtin_mips_subu_s_qb (v4i8, v4i8);
i32 __builtin_mips_addsc (i32, i32);
i32 __builtin_mips_addwc (i32, i32);
i32 __builtin_mips_modsub (i32, i32);
i32 __builtin_mips_raddu_w_qb (v4i8);
v2q15 __builtin_mips_absq_s_ph (v2q15);
q31 __builtin_mips_absq_s_w (q31);
v4i8 __builtin_mips_precrq_qb_ph (v2q15, v2q15);
v2q15 __builtin_mips_precrq_ph_w (q31, q31);
v2q15 __builtin_mips_precrq_rs_ph_w (q31, q31);
v4i8 __builtin_mips_precrqu_s_qb_ph (v2q15, v2q15);
q31 __builtin_mips_preceq_w_phl (v2q15);
q31 __builtin_mips_preceq_w_phr (v2q15);
v2q15 __builtin_mips_precequ_ph_qbl (v4i8);
v2q15 __builtin_mips_precequ_ph_qbr (v4i8);
v2q15 __builtin_mips_precequ_ph_qbla (v4i8);
v2q15 __builtin_mips_precequ_ph_qbra (v4i8);
```

```
v2q15 __builtin_mips_preceu_ph_qbl (v4i8);
v2q15 __builtin_mips_preceu_ph_qbr (v4i8);
v2q15 __builtin_mips_preceu_ph_qbla (v4i8);
v2q15 __builtin_mips_preceu_ph_qbra (v4i8);
v4i8 __builtin_mips_shll_qb (v4i8, imm0_7);
v4i8 __builtin_mips_shll_qb (v4i8, i32);
v2q15 __builtin_mips_shll_ph (v2q15, imm0_15);
v2q15 __builtin_mips_shll_ph (v2q15, i32);
v2q15 __builtin_mips_shll_s_ph (v2q15, imm0_15);
v2q15 __builtin_mips_shll_s_ph (v2q15, i32);
q31 __builtin_mips_shll_s_w (q31, imm0_31);
q31 __builtin_mips_shll_s_w (q31, i32);
v4i8 __builtin_mips_shrl_qb (v4i8, imm0_7);
v4i8 __builtin_mips_shrl_qb (v4i8, i32);
v2q15 __builtin_mips_shra_ph (v2q15, imm0_15);
v2q15 __builtin_mips_shra_ph (v2q15, i32);
v2q15 __builtin_mips_shra_r_ph (v2q15, imm0_15);
v2q15 __builtin_mips_shra_r_ph (v2q15, i32);
q31 __builtin_mips_shra_r_w (q31, imm0_31);
q31 __builtin_mips_shra_r_w (q31, i32);
v2q15 __builtin_mips_muleu_s_ph_qbl (v4i8, v2q15);
v2q15 __builtin_mips_muleu_s_ph_qbr (v4i8, v2q15);
v2q15 __builtin_mips_mulq_rs_ph (v2q15, v2q15);
q31 __builtin_mips_muleq_s_w_phl (v2q15, v2q15);
q31 __builtin_mips_muleq_s_w_phr (v2q15, v2q15);
a64 __builtin_mips_dpau_h_qbl (a64, v4i8, v4i8);
a64 __builtin_mips_dpau_h_qbr (a64, v4i8, v4i8);
a64 __builtin_mips_dpsu_h_qbl (a64, v4i8, v4i8);
a64 __builtin_mips_dpsu_h_qbr (a64, v4i8, v4i8);
a64 __builtin_mips_dpaq_s_w_ph (a64, v2q15, v2q15);
a64 __builtin_mips_dpaq_sa_l_w (a64, q31, q31);
a64 __builtin_mips_dpsq_s_w_ph (a64, v2q15, v2q15);
a64 __builtin_mips_dpsq_sa_l_w (a64, q31, q31);
a64 __builtin_mips_mulsaq_s_w_ph (a64, v2q15, v2q15);
a64 __builtin_mips_maq_s_w_phl (a64, v2q15, v2q15);
a64 __builtin_mips_maq_s_w_phr (a64, v2q15, v2q15);
a64 __builtin_mips_maq_sa_w_phl (a64, v2q15, v2q15);
a64 __builtin_mips_maq_sa_w_phr (a64, v2q15, v2q15);
i32 __builtin_mips_bitrev (i32);
i32 __builtin_mips_insv (i32, i32);
v4i8 __builtin_mips_repl_qb (imm0_255);
v4i8 __builtin_mips_repl_qb (i32);
v2q15 __builtin_mips_repl_ph (imm_n512_511);
v2q15 __builtin_mips_repl_ph (i32);
void __builtin_mips_cmpu_eq_qb (v4i8, v4i8);
void __builtin_mips_cmpu_lt_qb (v4i8, v4i8);
void __builtin_mips_cmpu_le_qb (v4i8, v4i8);
i32 __builtin_mips_cmpgu_eq_qb (v4i8, v4i8);
i32 __builtin_mips_cmpgu_lt_qb (v4i8, v4i8);
i32 __builtin_mips_cmpgu_le_qb (v4i8, v4i8);
void __builtin_mips_cmp_eq_ph (v2q15, v2q15);
void __builtin_mips_cmp_lt_ph (v2q15, v2q15);
void __builtin_mips_cmp_le_ph (v2q15, v2q15);
v4i8 __builtin_mips_pick_qb (v4i8, v4i8);
v2q15 __builtin_mips_pick_ph (v2q15, v2q15);
v2q15 __builtin_mips_packrl_ph (v2q15, v2q15);
i32 __builtin_mips_extr_w (a64, imm0_31);
i32 __builtin_mips_extr_w (a64, i32);
```

```
i32 __builtin_mips_extr_r_w (a64, imm0_31);
i32 __builtin_mips_extr_s_h (a64, i32);
i32 __builtin_mips_extr_rs_w (a64, imm0_31);
i32 __builtin_mips_extr_rs_w (a64, i32);
i32 __builtin_mips_extr_s_h (a64, imm0_31);
i32 __builtin_mips_extr_r_w (a64, i32);
i32 __builtin_mips_extp (a64, imm0_31);
i32 __builtin_mips_extp (a64, i32);
i32 __builtin_mips_extpdp (a64, imm0_31);
i32 __builtin_mips_extpdp (a64, i32);
a64 __builtin_mips_shilo (a64, imm_n32_31);
a64 __builtin_mips_shilo (a64, i32);
a64 __builtin_mips_mthlip (a64, i32);
void __builtin_mips_wrdsp (i32, imm0_63);
i32 __builtin_mips_rddsp (imm0_63);
i32 __builtin_mips_lbux (void *, i32);
i32 __builtin_mips_lhx (void *, i32);
i32 __builtin_mips_lwx (void *, i32);
a64 __builtin_mips_ldx (void *, i32); /* MIPS64 only */
i32 __builtin_mips_bposge32 (void);
a64 __builtin_mips_madd (a64, i32, i32);
a64 __builtin_mips_maddu (a64, ui32, ui32);
a64 __builtin_mips_msub (a64, i32, i32);
a64 __builtin_mips_msubu (a64, ui32, ui32);
a64 __builtin_mips_mult (i32, i32);
a64 __builtin_mips_multu (ui32, ui32);
```

The following built-in functions map directly to a particular MIPS DSP REV 2 instruction. Please refer to the architecture specification for details on what each instruction does.

```
v4q7 __builtin_mips_absq_s_qb (v4q7);
v2i16 __builtin_mips_addu_ph (v2i16, v2i16);
v2i16 __builtin_mips_addu_s_ph (v2i16, v2i16);
v4i8 __builtin_mips_adduh_qb (v4i8, v4i8);
v4i8 __builtin_mips_adduh_r_qb (v4i8, v4i8);
i32 __builtin_mips_append (i32, i32, imm0_31);
i32 __builtin_mips_balign (i32, i32, imm0_3);
i32 __builtin_mips_cmpgdu_eq_qb (v4i8, v4i8);
i32 __builtin_mips_cmpgdu_lt_qb (v4i8, v4i8);
i32 __builtin_mips_cmpgdu_le_qb (v4i8, v4i8);
a64 __builtin_mips_dpa_w_ph (a64, v2i16, v2i16);
a64 __builtin_mips_dps_w_ph (a64, v2i16, v2i16);
v2i16 __builtin_mips_mul_ph (v2i16, v2i16);
v2i16 __builtin_mips_mul_s_ph (v2i16, v2i16);
q31 __builtin_mips_mulq_rs_w (q31, q31);
v2q15 __builtin_mips_mulq_s_ph (v2q15, v2q15);
q31 __builtin_mips_mulq_s_w (q31, q31);
a64 __builtin_mips_mulsa_w_ph (a64, v2i16, v2i16);
v4i8 __builtin_mips_precr_qb_ph (v2i16, v2i16);
v2i16 __builtin_mips_precr_sra_ph_w (i32, i32, imm0_31);
v2i16 __builtin_mips_precr_sra_r_ph_w (i32, i32, imm0_31);
i32 __builtin_mips_prepend (i32, i32, imm0_31);
v4i8 __builtin_mips_shra_qb (v4i8, imm0_7);
v4i8 __builtin_mips_shra_r_qb (v4i8, imm0_7);
v4i8 __builtin_mips_shra_qb (v4i8, i32);
v4i8 __builtin_mips_shra_r_qb (v4i8, i32);
v2i16 __builtin_mips_shrl_ph (v2i16, imm0_15);
v2i16 __builtin_mips_shrl_ph (v2i16, i32);
v2i16 __builtin_mips_subu_ph (v2i16, v2i16);
```

```
v2i16 __builtin_mips_subu_s_ph (v2i16, v2i16);
v4i8 __builtin_mips_subuh_qb (v4i8, v4i8);
v4i8 __builtin_mips_subuh_r_qb (v4i8, v4i8);
v2q15 __builtin_mips_addqh_ph (v2q15, v2q15);
v2q15 __builtin_mips_addqh_r_ph (v2q15, v2q15);
q31 __builtin_mips_addqh_w (q31, q31);
q31 __builtin_mips_addqh_r_w (q31, q31);
v2q15 __builtin_mips_subqh_ph (v2q15, v2q15);
v2q15 __builtin_mips_subqh_r_ph (v2q15, v2q15);
q31 __builtin_mips_subqh_w (q31, q31);
q31 __builtin_mips_subqh_r_w (q31, q31);
a64 __builtin_mips_dpax_w_ph (a64, v2i16, v2i16);
a64 __builtin_mips_dpsx_w_ph (a64, v2i16, v2i16);
a64 __builtin_mips_dpaqx_s_w_ph (a64, v2q15, v2q15);
a64 __builtin_mips_dpaqx_sa_w_ph (a64, v2q15, v2q15);
a64 __builtin_mips_dpsqx_s_w_ph (a64, v2q15, v2q15);
a64 __builtin_mips_dpsqx_sa_w_ph (a64, v2q15, v2q15);
```

7.13.16 MIPS Paired-Single Support

The MIPS64 architecture includes a number of instructions that operate on pairs of single-precision floating-point values. Each pair is packed into a 64-bit floating-point register, with one element being designated the "upper half" and the other being designated the "lower half".

GCC supports paired-single operations using both the generic vector extensions (see Section 7.8 [Vector Extensions], page 850) and a collection of MIPS-specific built-in functions. Both kinds of support are enabled by the `-mpaired-single` command-line option.

The vector type associated with paired-single values is usually called `v2sf`. It can be defined in C as follows:

```
typedef float v2sf __attribute__ ((vector_size (8)));
```

`v2sf` values are initialized in the same way as aggregates. For example:

```
v2sf a = {1.5, 9.1};
v2sf b;
float e, f;
b = (v2sf) {e, f};
```

Note: The CPU's endianness determines which value is stored in the upper half of a register and which value is stored in the lower half. On little-endian targets, the first value is the lower one and the second value is the upper one. The opposite order applies to big-endian targets. For example, the code above sets the lower half of `a` to `1.5` on little-endian targets and `9.1` on big-endian targets.

7.13.17 MIPS Loongson Built-in Functions

GCC provides intrinsics to access the SIMD instructions provided by the ST Microelectronics Loongson-2E and -2F processors. These intrinsics, available after inclusion of the `loongson.h` header file, operate on the following 64-bit vector types:

- `uint8x8_t`, a vector of eight unsigned 8-bit integers;
- `uint16x4_t`, a vector of four unsigned 16-bit integers;
- `uint32x2_t`, a vector of two unsigned 32-bit integers;
- `int8x8_t`, a vector of eight signed 8-bit integers;

- `int16x4_t`, a vector of four signed 16-bit integers;
- `int32x2_t`, a vector of two signed 32-bit integers.

The intrinsics provided are listed below; each is named after the machine instruction to which it corresponds, with suffixes added as appropriate to distinguish intrinsics that expand to the same machine instruction yet have different argument types. Refer to the architecture documentation for a description of the functionality of each instruction.

```
int16x4_t packsswh (int32x2_t s, int32x2_t t);
int8x8_t packsshb (int16x4_t s, int16x4_t t);
uint8x8_t packushb (uint16x4_t s, uint16x4_t t);
uint32x2_t paddw_u (uint32x2_t s, uint32x2_t t);
uint16x4_t paddh_u (uint16x4_t s, uint16x4_t t);
uint8x8_t paddb_u (uint8x8_t s, uint8x8_t t);
int32x2_t paddw_s (int32x2_t s, int32x2_t t);
int16x4_t paddh_s (int16x4_t s, int16x4_t t);
int8x8_t paddb_s (int8x8_t s, int8x8_t t);
uint64_t paddd_u (uint64_t s, uint64_t t);
int64_t paddd_s (int64_t s, int64_t t);
int16x4_t paddsh (int16x4_t s, int16x4_t t);
int8x8_t paddsb (int8x8_t s, int8x8_t t);
uint16x4_t paddush (uint16x4_t s, uint16x4_t t);
uint8x8_t paddusb (uint8x8_t s, uint8x8_t t);
uint64_t pandn_ud (uint64_t s, uint64_t t);
uint32x2_t pandn_uw (uint32x2_t s, uint32x2_t t);
uint16x4_t pandn_uh (uint16x4_t s, uint16x4_t t);
uint8x8_t pandn_ub (uint8x8_t s, uint8x8_t t);
int64_t pandn_sd (int64_t s, int64_t t);
int32x2_t pandn_sw (int32x2_t s, int32x2_t t);
int16x4_t pandn_sh (int16x4_t s, int16x4_t t);
int8x8_t pandn_sb (int8x8_t s, int8x8_t t);
uint16x4_t pavgh (uint16x4_t s, uint16x4_t t);
uint8x8_t pavgb (uint8x8_t s, uint8x8_t t);
uint32x2_t pcmpeqw_u (uint32x2_t s, uint32x2_t t);
uint16x4_t pcmpeqh_u (uint16x4_t s, uint16x4_t t);
uint8x8_t pcmpeqb_u (uint8x8_t s, uint8x8_t t);
int32x2_t pcmpeqw_s (int32x2_t s, int32x2_t t);
int16x4_t pcmpeqh_s (int16x4_t s, int16x4_t t);
int8x8_t pcmpeqb_s (int8x8_t s, int8x8_t t);
uint32x2_t pcmpgtw_u (uint32x2_t s, uint32x2_t t);
uint16x4_t pcmpgth_u (uint16x4_t s, uint16x4_t t);
uint8x8_t pcmpgtb_u (uint8x8_t s, uint8x8_t t);
int32x2_t pcmpgtw_s (int32x2_t s, int32x2_t t);
int16x4_t pcmpgth_s (int16x4_t s, int16x4_t t);
int8x8_t pcmpgtb_s (int8x8_t s, int8x8_t t);
uint16x4_t pextrh_u (uint16x4_t s, int field);
int16x4_t pextrh_s (int16x4_t s, int field);
uint16x4_t pinsrh_0_u (uint16x4_t s, uint16x4_t t);
uint16x4_t pinsrh_1_u (uint16x4_t s, uint16x4_t t);
uint16x4_t pinsrh_2_u (uint16x4_t s, uint16x4_t t);
uint16x4_t pinsrh_3_u (uint16x4_t s, uint16x4_t t);
int16x4_t pinsrh_0_s (int16x4_t s, int16x4_t t);
int16x4_t pinsrh_1_s (int16x4_t s, int16x4_t t);
int16x4_t pinsrh_2_s (int16x4_t s, int16x4_t t);
int16x4_t pinsrh_3_s (int16x4_t s, int16x4_t t);
int32x2_t pmaddhw (int16x4_t s, int16x4_t t);
int16x4_t pmaxsh (int16x4_t s, int16x4_t t);
uint8x8_t pmaxub (uint8x8_t s, uint8x8_t t);
```

```
int16x4_t pminsh (int16x4_t s, int16x4_t t);
uint8x8_t pminub (uint8x8_t s, uint8x8_t t);
uint8x8_t pmovmskb_u (uint8x8_t s);
int8x8_t pmovmskb_s (int8x8_t s);
uint16x4_t pmulhuh (uint16x4_t s, uint16x4_t t);
int16x4_t pmulhh (int16x4_t s, int16x4_t t);
int16x4_t pmullh (int16x4_t s, int16x4_t t);
int64_t pmuluw (uint32x2_t s, uint32x2_t t);
uint8x8_t pasubub (uint8x8_t s, uint8x8_t t);
uint16x4_t biadd (uint8x8_t s);
uint16x4_t psadbh (uint8x8_t s, uint8x8_t t);
uint16x4_t pshufh_u (uint16x4_t dest, uint16x4_t s, uint8_t order);
int16x4_t pshufh_s (int16x4_t dest, int16x4_t s, uint8_t order);
uint16x4_t psllh_u (uint16x4_t s, uint8_t amount);
int16x4_t psllh_s (int16x4_t s, uint8_t amount);
uint32x2_t psllw_u (uint32x2_t s, uint8_t amount);
int32x2_t psllw_s (int32x2_t s, uint8_t amount);
uint16x4_t psrlh_u (uint16x4_t s, uint8_t amount);
int16x4_t psrlh_s (int16x4_t s, uint8_t amount);
uint32x2_t psrlw_u (uint32x2_t s, uint8_t amount);
int32x2_t psrlw_s (int32x2_t s, uint8_t amount);
uint16x4_t psrah_u (uint16x4_t s, uint8_t amount);
int16x4_t psrah_s (int16x4_t s, uint8_t amount);
uint32x2_t psraw_u (uint32x2_t s, uint8_t amount);
int32x2_t psraw_s (int32x2_t s, uint8_t amount);
uint32x2_t psubw_u (uint32x2_t s, uint32x2_t t);
uint16x4_t psubh_u (uint16x4_t s, uint16x4_t t);
uint8x8_t psubb_u (uint8x8_t s, uint8x8_t t);
int32x2_t psubw_s (int32x2_t s, int32x2_t t);
int16x4_t psubh_s (int16x4_t s, int16x4_t t);
int8x8_t psubb_s (int8x8_t s, int8x8_t t);
uint64_t psubd_u (uint64_t s, uint64_t t);
int64_t psubd_s (int64_t s, int64_t t);
int16x4_t psubsh (int16x4_t s, int16x4_t t);
int8x8_t psubsb (int8x8_t s, int8x8_t t);
uint16x4_t psubush (uint16x4_t s, uint16x4_t t);
uint8x8_t psubusb (uint8x8_t s, uint8x8_t t);
uint32x2_t punpckhwd_u (uint32x2_t s, uint32x2_t t);
uint16x4_t punpckhhw_u (uint16x4_t s, uint16x4_t t);
uint8x8_t punpckhbh_u (uint8x8_t s, uint8x8_t t);
int32x2_t punpckhwd_s (int32x2_t s, int32x2_t t);
int16x4_t punpckhhw_s (int16x4_t s, int16x4_t t);
int8x8_t punpckhbh_s (int8x8_t s, int8x8_t t);
uint32x2_t punpcklwd_u (uint32x2_t s, uint32x2_t t);
uint16x4_t punpcklhw_u (uint16x4_t s, uint16x4_t t);
uint8x8_t punpcklbh_u (uint8x8_t s, uint8x8_t t);
int32x2_t punpcklwd_s (int32x2_t s, int32x2_t t);
int16x4_t punpcklhw_s (int16x4_t s, int16x4_t t);
int8x8_t punpcklbh_s (int8x8_t s, int8x8_t t);
```

7.13.17.1 Paired-Single Arithmetic

The table below lists the `v2sf` operations for which hardware support exists. `a`, `b` and `c` are `v2sf` values and `x` is an integral value.

C code	**MIPS instruction**
`a + b`	`add.ps`
`a - b`	`sub.ps`

`-a`	`neg.ps`
`a * b`	`mul.ps`
`a * b + c`	`madd.ps`
`a * b - c`	`msub.ps`
`-(a * b + c)`	`nmadd.ps`
`-(a * b - c)`	`nmsub.ps`
`x ? a : b`	`movn.ps/movz.ps`

Note that the multiply-accumulate instructions can be disabled using the command-line option `-mno-fused-madd`.

7.13.17.2 Paired-Single Built-in Functions

The following paired-single functions map directly to a particular MIPS instruction. Please refer to the architecture specification for details on what each instruction does.

`v2sf __builtin_mips_pll_ps (v2sf, v2sf)`
: Pair lower lower (`pll.ps`).

`v2sf __builtin_mips_pul_ps (v2sf, v2sf)`
: Pair upper lower (`pul.ps`).

`v2sf __builtin_mips_plu_ps (v2sf, v2sf)`
: Pair lower upper (`plu.ps`).

`v2sf __builtin_mips_puu_ps (v2sf, v2sf)`
: Pair upper upper (`puu.ps`).

`v2sf __builtin_mips_cvt_ps_s (float, float)`
: Convert pair to paired single (`cvt.ps.s`).

`float __builtin_mips_cvt_s_pl (v2sf)`
: Convert pair lower to single (`cvt.s.pl`).

`float __builtin_mips_cvt_s_pu (v2sf)`
: Convert pair upper to single (`cvt.s.pu`).

`v2sf __builtin_mips_abs_ps (v2sf)`
: Absolute value (`abs.ps`).

`v2sf __builtin_mips_alnv_ps (v2sf, v2sf, int)`
: Align variable (`alnv.ps`).

  Note: The value of the third parameter must be 0 or 4 modulo 8, otherwise the result is unpredictable. Please read the instruction description for details.

The following multi-instruction functions are also available. In each case, *cond* can be any of the 16 floating-point conditions: `f`, `un`, `eq`, `ueq`, `olt`, `ult`, `ole`, `ule`, `sf`, `ngle`, `seq`, `ngl`, `lt`, `nge`, `le` or `ngt`.

`v2sf __builtin_mips_movt_c_`*`cond`*`_ps (v2sf `*`a`*`, v2sf `*`b`*`, v2sf `*`c`*`, v2sf `*`d`*`)`
`v2sf __builtin_mips_movf_c_`*`cond`*`_ps (v2sf `*`a`*`, v2sf `*`b`*`, v2sf `*`c`*`, v2sf `*`d`*`)`
: Conditional move based on floating-point comparison (`c.`*`cond`*`.ps`, `movt.ps/movf.ps`).

  The `movt` functions return the value *x* computed by:

```
c.cond.ps cc,a,b
```

```
mov.ps x,c
movt.ps x,d,cc
```

The `movf` functions are similar but use `movf.ps` instead of `movt.ps`.

`int __builtin_mips_upper_c_cond_ps (v2sf a, v2sf b)`
`int __builtin_mips_lower_c_cond_ps (v2sf a, v2sf b)`

Comparison of two paired-single values (`c.cond.ps`, `bc1t`/`bc1f`).

These functions compare *a* and *b* using `c.cond.ps` and return either the upper or lower half of the result. For example:

```
v2sf a, b;
if (__builtin_mips_upper_c_eq_ps (a, b))
  upper_halves_are_equal ();
else
  upper_halves_are_unequal ();

if (__builtin_mips_lower_c_eq_ps (a, b))
  lower_halves_are_equal ();
else
  lower_halves_are_unequal ();
```

7.13.17.3 MIPS-3D Built-in Functions

The MIPS-3D Application-Specific Extension (ASE) includes additional paired-single instructions that are designed to improve the performance of 3D graphics operations. Support for these instructions is controlled by the `-mips3d` command-line option.

The functions listed below map directly to a particular MIPS-3D instruction. Please refer to the architecture specification for more details on what each instruction does.

`v2sf __builtin_mips_addr_ps (v2sf, v2sf)`

Reduction add (`addr.ps`).

`v2sf __builtin_mips_mulr_ps (v2sf, v2sf)`

Reduction multiply (`mulr.ps`).

`v2sf __builtin_mips_cvt_pw_ps (v2sf)`

Convert paired single to paired word (`cvt.pw.ps`).

`v2sf __builtin_mips_cvt_ps_pw (v2sf)`

Convert paired word to paired single (`cvt.ps.pw`).

`float __builtin_mips_recip1_s (float)`
`double __builtin_mips_recip1_d (double)`
`v2sf __builtin_mips_recip1_ps (v2sf)`

Reduced-precision reciprocal (sequence step 1) (`recip1.fmt`).

`float __builtin_mips_recip2_s (float, float)`
`double __builtin_mips_recip2_d (double, double)`
`v2sf __builtin_mips_recip2_ps (v2sf, v2sf)`

Reduced-precision reciprocal (sequence step 2) (`recip2.fmt`).

`float __builtin_mips_rsqrt1_s (float)`
`double __builtin_mips_rsqrt1_d (double)`
`v2sf __builtin_mips_rsqrt1_ps (v2sf)`

Reduced-precision reciprocal square root (sequence step 1) (`rsqrt1.fmt`).

float __builtin_mips_rsqrt2_s (float, float)
double __builtin_mips_rsqrt2_d (double, double)
v2sf __builtin_mips_rsqrt2_ps (v2sf, v2sf)

Reduced-precision reciprocal square root (sequence step 2) (`rsqrt2.`*fmt*).

The following multi-instruction functions are also available. In each case, *cond* can be any of the 16 floating-point conditions: `f`, `un`, `eq`, `ueq`, `olt`, `ult`, `ole`, `ule`, `sf`, `ngle`, `seq`, `ngl`, `lt`, `nge`, `le` or `ngt`.

int __builtin_mips_cabs_*cond*_s (float *a*, float *b*)
int __builtin_mips_cabs_*cond*_d (double *a*, double *b*)

Absolute comparison of two scalar values (`cabs.`*cond*`.`*fmt*, `bc1t`/`bc1f`).

These functions compare *a* and *b* using `cabs.`*cond*`.s` or `cabs.`*cond*`.d` and return the result as a boolean value. For example:

```
float a, b;
if (__builtin_mips_cabs_eq_s (a, b))
  true ();
else
  false ();
```

int __builtin_mips_upper_cabs_*cond*_ps (v2sf *a*, v2sf *b*)
int __builtin_mips_lower_cabs_*cond*_ps (v2sf *a*, v2sf *b*)

Absolute comparison of two paired-single values (`cabs.`*cond*`.ps`, `bc1t`/`bc1f`).

These functions compare *a* and *b* using `cabs.`*cond*`.ps` and return either the upper or lower half of the result. For example:

```
v2sf a, b;
if (__builtin_mips_upper_cabs_eq_ps (a, b))
  upper_halves_are_equal ();
else
  upper_halves_are_unequal ();

if (__builtin_mips_lower_cabs_eq_ps (a, b))
  lower_halves_are_equal ();
else
  lower_halves_are_unequal ();
```

v2sf __builtin_mips_movt_cabs_*cond*_ps (v2sf *a*, v2sf *b*, v2sf *c*, v2sf *d*)
v2sf __builtin_mips_movf_cabs_*cond*_ps (v2sf *a*, v2sf *b*, v2sf *c*, v2sf *d*)

Conditional move based on absolute comparison (`cabs.`*cond*`.ps`, `movt.ps`/`movf.ps`).

The `movt` functions return the value *x* computed by:

```
cabs.cond.ps cc,a,b
mov.ps x,c
movt.ps x,d,cc
```

The `movf` functions are similar but use `movf.ps` instead of `movt.ps`.

int __builtin_mips_any_c_*cond*_ps (v2sf *a*, v2sf *b*)
int __builtin_mips_all_c_*cond*_ps (v2sf *a*, v2sf *b*)
int __builtin_mips_any_cabs_*cond*_ps (v2sf *a*, v2sf *b*)
int __builtin_mips_all_cabs_*cond*_ps (v2sf *a*, v2sf *b*)

Comparison of two paired-single values (`c.`*cond*`.ps`/`cabs.`*cond*`.ps`, `bc1any2t`/`bc1any2f`).

These functions compare *a* and *b* using `c.cond.ps` or `cabs.cond.ps`. The `any` forms return `true` if either result is `true` and the `all` forms return `true` if both results are `true`. For example:

```
v2sf a, b;
if (__builtin_mips_any_c_eq_ps (a, b))
  one_is_true ();
else
  both_are_false ();

if (__builtin_mips_all_c_eq_ps (a, b))
  both_are_true ();
else
  one_is_false ();
```

`int __builtin_mips_any_c_cond_4s (v2sf a, v2sf b, v2sf c, v2sf d)`
`int __builtin_mips_all_c_cond_4s (v2sf a, v2sf b, v2sf c, v2sf d)`
`int __builtin_mips_any_cabs_cond_4s (v2sf a, v2sf b, v2sf c, v2sf d)`
`int __builtin_mips_all_cabs_cond_4s (v2sf a, v2sf b, v2sf c, v2sf d)`

Comparison of four paired-single values (`c.cond.ps`/`cabs.cond.ps`, `bc1any4t`/`bc1any4f`).

These functions use `c.cond.ps` or `cabs.cond.ps` to compare *a* with *b* and to compare *c* with *d*. The `any` forms return `true` if any of the four results are `true` and the `all` forms return `true` if all four results are `true`. For example:

```
v2sf a, b, c, d;
if (__builtin_mips_any_c_eq_4s (a, b, c, d))
  some_are_true ();
else
  all_are_false ();

if (__builtin_mips_all_c_eq_4s (a, b, c, d))
  all_are_true ();
else
  some_are_false ();
```

7.13.18 MIPS SIMD Architecture (MSA) Support

GCC provides intrinsics to access the SIMD instructions provided by the MSA MIPS SIMD Architecture. The interface is made available by including `<msa.h>` and using `-mmsa -mhard-float -mfp64 -mnan=2008`. For each `__builtin_msa_*`, there is a shortened name of the intrinsic, `__msa_*`.

MSA implements 128-bit wide vector registers, operating on 8-, 16-, 32- and 64-bit integer, 16- and 32-bit fixed-point, or 32- and 64-bit floating point data elements. The following vectors typedefs are included in `msa.h`:

- `v16i8`, a vector of sixteen signed 8-bit integers;
- `v16u8`, a vector of sixteen unsigned 8-bit integers;
- `v8i16`, a vector of eight signed 16-bit integers;
- `v8u16`, a vector of eight unsigned 16-bit integers;
- `v4i32`, a vector of four signed 32-bit integers;
- `v4u32`, a vector of four unsigned 32-bit integers;
- `v2i64`, a vector of two signed 64-bit integers;

- `v2u64`, a vector of two unsigned 64-bit integers;
- `v4f32`, a vector of four 32-bit floats;
- `v2f64`, a vector of two 64-bit doubles.

Instructions and corresponding built-ins may have additional restrictions and/or input/output values manipulated:

- `imm0_1`, an integer literal in range 0 to 1;
- `imm0_3`, an integer literal in range 0 to 3;
- `imm0_7`, an integer literal in range 0 to 7;
- `imm0_15`, an integer literal in range 0 to 15;
- `imm0_31`, an integer literal in range 0 to 31;
- `imm0_63`, an integer literal in range 0 to 63;
- `imm0_255`, an integer literal in range 0 to 255;
- `imm_n16_15`, an integer literal in range -16 to 15;
- `imm_n512_511`, an integer literal in range -512 to 511;
- `imm_n1024_1022`, an integer literal in range -512 to 511 left shifted by 1 bit, i.e., -1024, -1022, . . . , 1020, 1022;
- `imm_n2048_2044`, an integer literal in range -512 to 511 left shifted by 2 bits, i.e., -2048, -2044, . . . , 2040, 2044;
- `imm_n4096_4088`, an integer literal in range -512 to 511 left shifted by 3 bits, i.e., -4096, -4088, . . . , 4080, 4088;
- `imm1_4`, an integer literal in range 1 to 4;
- `i32, i64, u32, u64, f32, f64`, defined as follows:

```
{
typedef int i32;
#if __LONG_MAX__ == __LONG_LONG_MAX__
typedef long i64;
#else
typedef long long i64;
#endif

typedef unsigned int u32;
#if __LONG_MAX__ == __LONG_LONG_MAX__
typedef unsigned long u64;
#else
typedef unsigned long long u64;
#endif

typedef double f64;
typedef float f32;
}
```

7.13.18.1 MIPS SIMD Architecture Built-in Functions

The intrinsics provided are listed below; each is named after the machine instruction.

```
v16i8 __builtin_msa_add_a_b (v16i8, v16i8);
v8i16 __builtin_msa_add_a_h (v8i16, v8i16);
v4i32 __builtin_msa_add_a_w (v4i32, v4i32);
v2i64 __builtin_msa_add_a_d (v2i64, v2i64);
```

```
v16i8 __builtin_msa_adds_a_b (v16i8, v16i8);
v8i16 __builtin_msa_adds_a_h (v8i16, v8i16);
v4i32 __builtin_msa_adds_a_w (v4i32, v4i32);
v2i64 __builtin_msa_adds_a_d (v2i64, v2i64);

v16i8 __builtin_msa_adds_s_b (v16i8, v16i8);
v8i16 __builtin_msa_adds_s_h (v8i16, v8i16);
v4i32 __builtin_msa_adds_s_w (v4i32, v4i32);
v2i64 __builtin_msa_adds_s_d (v2i64, v2i64);

v16u8 __builtin_msa_adds_u_b (v16u8, v16u8);
v8u16 __builtin_msa_adds_u_h (v8u16, v8u16);
v4u32 __builtin_msa_adds_u_w (v4u32, v4u32);
v2u64 __builtin_msa_adds_u_d (v2u64, v2u64);

v16i8 __builtin_msa_addv_b (v16i8, v16i8);
v8i16 __builtin_msa_addv_h (v8i16, v8i16);
v4i32 __builtin_msa_addv_w (v4i32, v4i32);
v2i64 __builtin_msa_addv_d (v2i64, v2i64);

v16i8 __builtin_msa_addvi_b (v16i8, imm0_31);
v8i16 __builtin_msa_addvi_h (v8i16, imm0_31);
v4i32 __builtin_msa_addvi_w (v4i32, imm0_31);
v2i64 __builtin_msa_addvi_d (v2i64, imm0_31);

v16u8 __builtin_msa_and_v (v16u8, v16u8);

v16u8 __builtin_msa_andi_b (v16u8, imm0_255);

v16i8 __builtin_msa_asub_s_b (v16i8, v16i8);
v8i16 __builtin_msa_asub_s_h (v8i16, v8i16);
v4i32 __builtin_msa_asub_s_w (v4i32, v4i32);
v2i64 __builtin_msa_asub_s_d (v2i64, v2i64);

v16u8 __builtin_msa_asub_u_b (v16u8, v16u8);
v8u16 __builtin_msa_asub_u_h (v8u16, v8u16);
v4u32 __builtin_msa_asub_u_w (v4u32, v4u32);
v2u64 __builtin_msa_asub_u_d (v2u64, v2u64);

v16i8 __builtin_msa_ave_s_b (v16i8, v16i8);
v8i16 __builtin_msa_ave_s_h (v8i16, v8i16);
v4i32 __builtin_msa_ave_s_w (v4i32, v4i32);
v2i64 __builtin_msa_ave_s_d (v2i64, v2i64);

v16u8 __builtin_msa_ave_u_b (v16u8, v16u8);
v8u16 __builtin_msa_ave_u_h (v8u16, v8u16);
v4u32 __builtin_msa_ave_u_w (v4u32, v4u32);
v2u64 __builtin_msa_ave_u_d (v2u64, v2u64);

v16i8 __builtin_msa_aver_s_b (v16i8, v16i8);
v8i16 __builtin_msa_aver_s_h (v8i16, v8i16);
v4i32 __builtin_msa_aver_s_w (v4i32, v4i32);
v2i64 __builtin_msa_aver_s_d (v2i64, v2i64);

v16u8 __builtin_msa_aver_u_b (v16u8, v16u8);
v8u16 __builtin_msa_aver_u_h (v8u16, v8u16);
v4u32 __builtin_msa_aver_u_w (v4u32, v4u32);
```

```
v2u64 __builtin_msa_aver_u_d (v2u64, v2u64);

v16u8 __builtin_msa_bclr_b (v16u8, v16u8);
v8u16 __builtin_msa_bclr_h (v8u16, v8u16);
v4u32 __builtin_msa_bclr_w (v4u32, v4u32);
v2u64 __builtin_msa_bclr_d (v2u64, v2u64);

v16u8 __builtin_msa_bclri_b (v16u8, imm0_7);
v8u16 __builtin_msa_bclri_h (v8u16, imm0_15);
v4u32 __builtin_msa_bclri_w (v4u32, imm0_31);
v2u64 __builtin_msa_bclri_d (v2u64, imm0_63);

v16u8 __builtin_msa_binsl_b (v16u8, v16u8, v16u8);
v8u16 __builtin_msa_binsl_h (v8u16, v8u16, v8u16);
v4u32 __builtin_msa_binsl_w (v4u32, v4u32, v4u32);
v2u64 __builtin_msa_binsl_d (v2u64, v2u64, v2u64);

v16u8 __builtin_msa_binsli_b (v16u8, v16u8, imm0_7);
v8u16 __builtin_msa_binsli_h (v8u16, v8u16, imm0_15);
v4u32 __builtin_msa_binsli_w (v4u32, v4u32, imm0_31);
v2u64 __builtin_msa_binsli_d (v2u64, v2u64, imm0_63);

v16u8 __builtin_msa_binsr_b (v16u8, v16u8, v16u8);
v8u16 __builtin_msa_binsr_h (v8u16, v8u16, v8u16);
v4u32 __builtin_msa_binsr_w (v4u32, v4u32, v4u32);
v2u64 __builtin_msa_binsr_d (v2u64, v2u64, v2u64);

v16u8 __builtin_msa_binsri_b (v16u8, v16u8, imm0_7);
v8u16 __builtin_msa_binsri_h (v8u16, v8u16, imm0_15);
v4u32 __builtin_msa_binsri_w (v4u32, v4u32, imm0_31);
v2u64 __builtin_msa_binsri_d (v2u64, v2u64, imm0_63);

v16u8 __builtin_msa_bmnz_v (v16u8, v16u8, v16u8);

v16u8 __builtin_msa_bmnzi_b (v16u8, v16u8, imm0_255);

v16u8 __builtin_msa_bmz_v (v16u8, v16u8, v16u8);

v16u8 __builtin_msa_bmzi_b (v16u8, v16u8, imm0_255);

v16u8 __builtin_msa_bneg_b (v16u8, v16u8);
v8u16 __builtin_msa_bneg_h (v8u16, v8u16);
v4u32 __builtin_msa_bneg_w (v4u32, v4u32);
v2u64 __builtin_msa_bneg_d (v2u64, v2u64);

v16u8 __builtin_msa_bnegi_b (v16u8, imm0_7);
v8u16 __builtin_msa_bnegi_h (v8u16, imm0_15);
v4u32 __builtin_msa_bnegi_w (v4u32, imm0_31);
v2u64 __builtin_msa_bnegi_d (v2u64, imm0_63);

i32 __builtin_msa_bnz_b (v16u8);
i32 __builtin_msa_bnz_h (v8u16);
i32 __builtin_msa_bnz_w (v4u32);
i32 __builtin_msa_bnz_d (v2u64);

i32 __builtin_msa_bnz_v (v16u8);

v16u8 __builtin_msa_bsel_v (v16u8, v16u8, v16u8);
```

```
v16u8 __builtin_msa_bseli_b (v16u8, v16u8, imm0_255);

v16u8 __builtin_msa_bset_b (v16u8, v16u8);
v8u16 __builtin_msa_bset_h (v8u16, v8u16);
v4u32 __builtin_msa_bset_w (v4u32, v4u32);
v2u64 __builtin_msa_bset_d (v2u64, v2u64);

v16u8 __builtin_msa_bseti_b (v16u8, imm0_7);
v8u16 __builtin_msa_bseti_h (v8u16, imm0_15);
v4u32 __builtin_msa_bseti_w (v4u32, imm0_31);
v2u64 __builtin_msa_bseti_d (v2u64, imm0_63);

i32 __builtin_msa_bz_b (v16u8);
i32 __builtin_msa_bz_h (v8u16);
i32 __builtin_msa_bz_w (v4u32);
i32 __builtin_msa_bz_d (v2u64);

i32 __builtin_msa_bz_v (v16u8);

v16i8 __builtin_msa_ceq_b (v16i8, v16i8);
v8i16 __builtin_msa_ceq_h (v8i16, v8i16);
v4i32 __builtin_msa_ceq_w (v4i32, v4i32);
v2i64 __builtin_msa_ceq_d (v2i64, v2i64);

v16i8 __builtin_msa_ceqi_b (v16i8, imm_n16_15);
v8i16 __builtin_msa_ceqi_h (v8i16, imm_n16_15);
v4i32 __builtin_msa_ceqi_w (v4i32, imm_n16_15);
v2i64 __builtin_msa_ceqi_d (v2i64, imm_n16_15);

i32 __builtin_msa_cfcmsa (imm0_31);

v16i8 __builtin_msa_cle_s_b (v16i8, v16i8);
v8i16 __builtin_msa_cle_s_h (v8i16, v8i16);
v4i32 __builtin_msa_cle_s_w (v4i32, v4i32);
v2i64 __builtin_msa_cle_s_d (v2i64, v2i64);

v16i8 __builtin_msa_cle_u_b (v16u8, v16u8);
v8i16 __builtin_msa_cle_u_h (v8u16, v8u16);
v4i32 __builtin_msa_cle_u_w (v4u32, v4u32);
v2i64 __builtin_msa_cle_u_d (v2u64, v2u64);

v16i8 __builtin_msa_clei_s_b (v16i8, imm_n16_15);
v8i16 __builtin_msa_clei_s_h (v8i16, imm_n16_15);
v4i32 __builtin_msa_clei_s_w (v4i32, imm_n16_15);
v2i64 __builtin_msa_clei_s_d (v2i64, imm_n16_15);

v16i8 __builtin_msa_clei_u_b (v16u8, imm0_31);
v8i16 __builtin_msa_clei_u_h (v8u16, imm0_31);
v4i32 __builtin_msa_clei_u_w (v4u32, imm0_31);
v2i64 __builtin_msa_clei_u_d (v2u64, imm0_31);

v16i8 __builtin_msa_clt_s_b (v16i8, v16i8);
v8i16 __builtin_msa_clt_s_h (v8i16, v8i16);
v4i32 __builtin_msa_clt_s_w (v4i32, v4i32);
v2i64 __builtin_msa_clt_s_d (v2i64, v2i64);

v16i8 __builtin_msa_clt_u_b (v16u8, v16u8);
```

```
v8i16 __builtin_msa_clt_u_h (v8u16, v8u16);
v4i32 __builtin_msa_clt_u_w (v4u32, v4u32);
v2i64 __builtin_msa_clt_u_d (v2u64, v2u64);

v16i8 __builtin_msa_clti_s_b (v16i8, imm_n16_15);
v8i16 __builtin_msa_clti_s_h (v8i16, imm_n16_15);
v4i32 __builtin_msa_clti_s_w (v4i32, imm_n16_15);
v2i64 __builtin_msa_clti_s_d (v2i64, imm_n16_15);

v16i8 __builtin_msa_clti_u_b (v16u8, imm0_31);
v8i16 __builtin_msa_clti_u_h (v8u16, imm0_31);
v4i32 __builtin_msa_clti_u_w (v4u32, imm0_31);
v2i64 __builtin_msa_clti_u_d (v2u64, imm0_31);

i32 __builtin_msa_copy_s_b (v16i8, imm0_15);
i32 __builtin_msa_copy_s_h (v8i16, imm0_7);
i32 __builtin_msa_copy_s_w (v4i32, imm0_3);
i64 __builtin_msa_copy_s_d (v2i64, imm0_1);

u32 __builtin_msa_copy_u_b (v16i8, imm0_15);
u32 __builtin_msa_copy_u_h (v8i16, imm0_7);
u32 __builtin_msa_copy_u_w (v4i32, imm0_3);
u64 __builtin_msa_copy_u_d (v2i64, imm0_1);

void __builtin_msa_ctcmsa (imm0_31, i32);

v16i8 __builtin_msa_div_s_b (v16i8, v16i8);
v8i16 __builtin_msa_div_s_h (v8i16, v8i16);
v4i32 __builtin_msa_div_s_w (v4i32, v4i32);
v2i64 __builtin_msa_div_s_d (v2i64, v2i64);

v16u8 __builtin_msa_div_u_b (v16u8, v16u8);
v8u16 __builtin_msa_div_u_h (v8u16, v8u16);
v4u32 __builtin_msa_div_u_w (v4u32, v4u32);
v2u64 __builtin_msa_div_u_d (v2u64, v2u64);

v8i16 __builtin_msa_dotp_s_h (v16i8, v16i8);
v4i32 __builtin_msa_dotp_s_w (v8i16, v8i16);
v2i64 __builtin_msa_dotp_s_d (v4i32, v4i32);

v8u16 __builtin_msa_dotp_u_h (v16u8, v16u8);
v4u32 __builtin_msa_dotp_u_w (v8u16, v8u16);
v2u64 __builtin_msa_dotp_u_d (v4u32, v4u32);

v8i16 __builtin_msa_dpadd_s_h (v8i16, v16i8, v16i8);
v4i32 __builtin_msa_dpadd_s_w (v4i32, v8i16, v8i16);
v2i64 __builtin_msa_dpadd_s_d (v2i64, v4i32, v4i32);

v8u16 __builtin_msa_dpadd_u_h (v8u16, v16u8, v16u8);
v4u32 __builtin_msa_dpadd_u_w (v4u32, v8u16, v8u16);
v2u64 __builtin_msa_dpadd_u_d (v2u64, v4u32, v4u32);

v8i16 __builtin_msa_dpsub_s_h (v8i16, v16i8, v16i8);
v4i32 __builtin_msa_dpsub_s_w (v4i32, v8i16, v8i16);
v2i64 __builtin_msa_dpsub_s_d (v2i64, v4i32, v4i32);

v8i16 __builtin_msa_dpsub_u_h (v8i16, v16u8, v16u8);
v4i32 __builtin_msa_dpsub_u_w (v4i32, v8u16, v8u16);
```

```
v2i64 __builtin_msa_dpsub_u_d (v2i64, v4u32, v4u32);

v4f32 __builtin_msa_fadd_w (v4f32, v4f32);
v2f64 __builtin_msa_fadd_d (v2f64, v2f64);

v4i32 __builtin_msa_fcaf_w (v4f32, v4f32);
v2i64 __builtin_msa_fcaf_d (v2f64, v2f64);

v4i32 __builtin_msa_fceq_w (v4f32, v4f32);
v2i64 __builtin_msa_fceq_d (v2f64, v2f64);

v4i32 __builtin_msa_fclass_w (v4f32);
v2i64 __builtin_msa_fclass_d (v2f64);

v4i32 __builtin_msa_fcle_w (v4f32, v4f32);
v2i64 __builtin_msa_fcle_d (v2f64, v2f64);

v4i32 __builtin_msa_fclt_w (v4f32, v4f32);
v2i64 __builtin_msa_fclt_d (v2f64, v2f64);

v4i32 __builtin_msa_fcne_w (v4f32, v4f32);
v2i64 __builtin_msa_fcne_d (v2f64, v2f64);

v4i32 __builtin_msa_fcor_w (v4f32, v4f32);
v2i64 __builtin_msa_fcor_d (v2f64, v2f64);

v4i32 __builtin_msa_fcueq_w (v4f32, v4f32);
v2i64 __builtin_msa_fcueq_d (v2f64, v2f64);

v4i32 __builtin_msa_fcule_w (v4f32, v4f32);
v2i64 __builtin_msa_fcule_d (v2f64, v2f64);

v4i32 __builtin_msa_fcult_w (v4f32, v4f32);
v2i64 __builtin_msa_fcult_d (v2f64, v2f64);

v4i32 __builtin_msa_fcun_w (v4f32, v4f32);
v2i64 __builtin_msa_fcun_d (v2f64, v2f64);

v4i32 __builtin_msa_fcune_w (v4f32, v4f32);
v2i64 __builtin_msa_fcune_d (v2f64, v2f64);

v4f32 __builtin_msa_fdiv_w (v4f32, v4f32);
v2f64 __builtin_msa_fdiv_d (v2f64, v2f64);

v8i16 __builtin_msa_fexdo_h (v4f32, v4f32);
v4f32 __builtin_msa_fexdo_w (v2f64, v2f64);

v4f32 __builtin_msa_fexp2_w (v4f32, v4i32);
v2f64 __builtin_msa_fexp2_d (v2f64, v2i64);

v4f32 __builtin_msa_fexupl_w (v8i16);
v2f64 __builtin_msa_fexupl_d (v4f32);

v4f32 __builtin_msa_fexupr_w (v8i16);
v2f64 __builtin_msa_fexupr_d (v4f32);

v4f32 __builtin_msa_ffint_s_w (v4i32);
v2f64 __builtin_msa_ffint_s_d (v2i64);
```

```
v4f32 __builtin_msa_ffint_u_w (v4u32);
v2f64 __builtin_msa_ffint_u_d (v2u64);

v4f32 __builtin_msa_ffql_w (v8i16);
v2f64 __builtin_msa_ffql_d (v4i32);

v4f32 __builtin_msa_ffqr_w (v8i16);
v2f64 __builtin_msa_ffqr_d (v4i32);

v16i8 __builtin_msa_fill_b (i32);
v8i16 __builtin_msa_fill_h (i32);
v4i32 __builtin_msa_fill_w (i32);
v2i64 __builtin_msa_fill_d (i64);

v4f32 __builtin_msa_flog2_w (v4f32);
v2f64 __builtin_msa_flog2_d (v2f64);

v4f32 __builtin_msa_fmadd_w (v4f32, v4f32, v4f32);
v2f64 __builtin_msa_fmadd_d (v2f64, v2f64, v2f64);

v4f32 __builtin_msa_fmax_w (v4f32, v4f32);
v2f64 __builtin_msa_fmax_d (v2f64, v2f64);

v4f32 __builtin_msa_fmax_a_w (v4f32, v4f32);
v2f64 __builtin_msa_fmax_a_d (v2f64, v2f64);

v4f32 __builtin_msa_fmin_w (v4f32, v4f32);
v2f64 __builtin_msa_fmin_d (v2f64, v2f64);

v4f32 __builtin_msa_fmin_a_w (v4f32, v4f32);
v2f64 __builtin_msa_fmin_a_d (v2f64, v2f64);

v4f32 __builtin_msa_fmsub_w (v4f32, v4f32, v4f32);
v2f64 __builtin_msa_fmsub_d (v2f64, v2f64, v2f64);

v4f32 __builtin_msa_fmul_w (v4f32, v4f32);
v2f64 __builtin_msa_fmul_d (v2f64, v2f64);

v4f32 __builtin_msa_frint_w (v4f32);
v2f64 __builtin_msa_frint_d (v2f64);

v4f32 __builtin_msa_frcp_w (v4f32);
v2f64 __builtin_msa_frcp_d (v2f64);

v4f32 __builtin_msa_frsqrt_w (v4f32);
v2f64 __builtin_msa_frsqrt_d (v2f64);

v4i32 __builtin_msa_fsaf_w (v4f32, v4f32);
v2i64 __builtin_msa_fsaf_d (v2f64, v2f64);

v4i32 __builtin_msa_fseq_w (v4f32, v4f32);
v2i64 __builtin_msa_fseq_d (v2f64, v2f64);

v4i32 __builtin_msa_fsle_w (v4f32, v4f32);
v2i64 __builtin_msa_fsle_d (v2f64, v2f64);

v4i32 __builtin_msa_fslt_w (v4f32, v4f32);
```

```
v2i64 __builtin_msa_fslt_d (v2f64, v2f64);

v4i32 __builtin_msa_fsne_w (v4f32, v4f32);
v2i64 __builtin_msa_fsne_d (v2f64, v2f64);

v4i32 __builtin_msa_fsor_w (v4f32, v4f32);
v2i64 __builtin_msa_fsor_d (v2f64, v2f64);

v4f32 __builtin_msa_fsqrt_w (v4f32);
v2f64 __builtin_msa_fsqrt_d (v2f64);

v4f32 __builtin_msa_fsub_w (v4f32, v4f32);
v2f64 __builtin_msa_fsub_d (v2f64, v2f64);

v4i32 __builtin_msa_fsueq_w (v4f32, v4f32);
v2i64 __builtin_msa_fsueq_d (v2f64, v2f64);

v4i32 __builtin_msa_fsule_w (v4f32, v4f32);
v2i64 __builtin_msa_fsule_d (v2f64, v2f64);

v4i32 __builtin_msa_fsult_w (v4f32, v4f32);
v2i64 __builtin_msa_fsult_d (v2f64, v2f64);

v4i32 __builtin_msa_fsun_w (v4f32, v4f32);
v2i64 __builtin_msa_fsun_d (v2f64, v2f64);

v4i32 __builtin_msa_fsune_w (v4f32, v4f32);
v2i64 __builtin_msa_fsune_d (v2f64, v2f64);

v4i32 __builtin_msa_ftint_s_w (v4f32);
v2i64 __builtin_msa_ftint_s_d (v2f64);

v4u32 __builtin_msa_ftint_u_w (v4f32);
v2u64 __builtin_msa_ftint_u_d (v2f64);

v8i16 __builtin_msa_ftq_h (v4f32, v4f32);
v4i32 __builtin_msa_ftq_w (v2f64, v2f64);

v4i32 __builtin_msa_ftrunc_s_w (v4f32);
v2i64 __builtin_msa_ftrunc_s_d (v2f64);

v4u32 __builtin_msa_ftrunc_u_w (v4f32);
v2u64 __builtin_msa_ftrunc_u_d (v2f64);

v8i16 __builtin_msa_hadd_s_h (v16i8, v16i8);
v4i32 __builtin_msa_hadd_s_w (v8i16, v8i16);
v2i64 __builtin_msa_hadd_s_d (v4i32, v4i32);

v8u16 __builtin_msa_hadd_u_h (v16u8, v16u8);
v4u32 __builtin_msa_hadd_u_w (v8u16, v8u16);
v2u64 __builtin_msa_hadd_u_d (v4u32, v4u32);

v8i16 __builtin_msa_hsub_s_h (v16i8, v16i8);
v4i32 __builtin_msa_hsub_s_w (v8i16, v8i16);
v2i64 __builtin_msa_hsub_s_d (v4i32, v4i32);

v8i16 __builtin_msa_hsub_u_h (v16u8, v16u8);
v4i32 __builtin_msa_hsub_u_w (v8u16, v8u16);
```

```
v2i64 __builtin_msa_hsub_u_d (v4u32, v4u32);

v16i8 __builtin_msa_ilvev_b (v16i8, v16i8);
v8i16 __builtin_msa_ilvev_h (v8i16, v8i16);
v4i32 __builtin_msa_ilvev_w (v4i32, v4i32);
v2i64 __builtin_msa_ilvev_d (v2i64, v2i64);

v16i8 __builtin_msa_ilvl_b (v16i8, v16i8);
v8i16 __builtin_msa_ilvl_h (v8i16, v8i16);
v4i32 __builtin_msa_ilvl_w (v4i32, v4i32);
v2i64 __builtin_msa_ilvl_d (v2i64, v2i64);

v16i8 __builtin_msa_ilvod_b (v16i8, v16i8);
v8i16 __builtin_msa_ilvod_h (v8i16, v8i16);
v4i32 __builtin_msa_ilvod_w (v4i32, v4i32);
v2i64 __builtin_msa_ilvod_d (v2i64, v2i64);

v16i8 __builtin_msa_ilvr_b (v16i8, v16i8);
v8i16 __builtin_msa_ilvr_h (v8i16, v8i16);
v4i32 __builtin_msa_ilvr_w (v4i32, v4i32);
v2i64 __builtin_msa_ilvr_d (v2i64, v2i64);

v16i8 __builtin_msa_insert_b (v16i8, imm0_15, i32);
v8i16 __builtin_msa_insert_h (v8i16, imm0_7, i32);
v4i32 __builtin_msa_insert_w (v4i32, imm0_3, i32);
v2i64 __builtin_msa_insert_d (v2i64, imm0_1, i64);

v16i8 __builtin_msa_insve_b (v16i8, imm0_15, v16i8);
v8i16 __builtin_msa_insve_h (v8i16, imm0_7, v8i16);
v4i32 __builtin_msa_insve_w (v4i32, imm0_3, v4i32);
v2i64 __builtin_msa_insve_d (v2i64, imm0_1, v2i64);

v16i8 __builtin_msa_ld_b (const void *, imm_n512_511);
v8i16 __builtin_msa_ld_h (const void *, imm_n1024_1022);
v4i32 __builtin_msa_ld_w (const void *, imm_n2048_2044);
v2i64 __builtin_msa_ld_d (const void *, imm_n4096_4088);

v16i8 __builtin_msa_ldi_b (imm_n512_511);
v8i16 __builtin_msa_ldi_h (imm_n512_511);
v4i32 __builtin_msa_ldi_w (imm_n512_511);
v2i64 __builtin_msa_ldi_d (imm_n512_511);

v8i16 __builtin_msa_madd_q_h (v8i16, v8i16, v8i16);
v4i32 __builtin_msa_madd_q_w (v4i32, v4i32, v4i32);

v8i16 __builtin_msa_maddr_q_h (v8i16, v8i16, v8i16);
v4i32 __builtin_msa_maddr_q_w (v4i32, v4i32, v4i32);

v16i8 __builtin_msa_maddv_b (v16i8, v16i8, v16i8);
v8i16 __builtin_msa_maddv_h (v8i16, v8i16, v8i16);
v4i32 __builtin_msa_maddv_w (v4i32, v4i32, v4i32);
v2i64 __builtin_msa_maddv_d (v2i64, v2i64, v2i64);

v16i8 __builtin_msa_max_a_b (v16i8, v16i8);
v8i16 __builtin_msa_max_a_h (v8i16, v8i16);
v4i32 __builtin_msa_max_a_w (v4i32, v4i32);
v2i64 __builtin_msa_max_a_d (v2i64, v2i64);
```

```
v16i8 __builtin_msa_max_s_b (v16i8, v16i8);
v8i16 __builtin_msa_max_s_h (v8i16, v8i16);
v4i32 __builtin_msa_max_s_w (v4i32, v4i32);
v2i64 __builtin_msa_max_s_d (v2i64, v2i64);

v16u8 __builtin_msa_max_u_b (v16u8, v16u8);
v8u16 __builtin_msa_max_u_h (v8u16, v8u16);
v4u32 __builtin_msa_max_u_w (v4u32, v4u32);
v2u64 __builtin_msa_max_u_d (v2u64, v2u64);

v16i8 __builtin_msa_maxi_s_b (v16i8, imm_n16_15);
v8i16 __builtin_msa_maxi_s_h (v8i16, imm_n16_15);
v4i32 __builtin_msa_maxi_s_w (v4i32, imm_n16_15);
v2i64 __builtin_msa_maxi_s_d (v2i64, imm_n16_15);

v16u8 __builtin_msa_maxi_u_b (v16u8, imm0_31);
v8u16 __builtin_msa_maxi_u_h (v8u16, imm0_31);
v4u32 __builtin_msa_maxi_u_w (v4u32, imm0_31);
v2u64 __builtin_msa_maxi_u_d (v2u64, imm0_31);

v16i8 __builtin_msa_min_a_b (v16i8, v16i8);
v8i16 __builtin_msa_min_a_h (v8i16, v8i16);
v4i32 __builtin_msa_min_a_w (v4i32, v4i32);
v2i64 __builtin_msa_min_a_d (v2i64, v2i64);

v16i8 __builtin_msa_min_s_b (v16i8, v16i8);
v8i16 __builtin_msa_min_s_h (v8i16, v8i16);
v4i32 __builtin_msa_min_s_w (v4i32, v4i32);
v2i64 __builtin_msa_min_s_d (v2i64, v2i64);

v16u8 __builtin_msa_min_u_b (v16u8, v16u8);
v8u16 __builtin_msa_min_u_h (v8u16, v8u16);
v4u32 __builtin_msa_min_u_w (v4u32, v4u32);
v2u64 __builtin_msa_min_u_d (v2u64, v2u64);

v16i8 __builtin_msa_mini_s_b (v16i8, imm_n16_15);
v8i16 __builtin_msa_mini_s_h (v8i16, imm_n16_15);
v4i32 __builtin_msa_mini_s_w (v4i32, imm_n16_15);
v2i64 __builtin_msa_mini_s_d (v2i64, imm_n16_15);

v16u8 __builtin_msa_mini_u_b (v16u8, imm0_31);
v8u16 __builtin_msa_mini_u_h (v8u16, imm0_31);
v4u32 __builtin_msa_mini_u_w (v4u32, imm0_31);
v2u64 __builtin_msa_mini_u_d (v2u64, imm0_31);

v16i8 __builtin_msa_mod_s_b (v16i8, v16i8);
v8i16 __builtin_msa_mod_s_h (v8i16, v8i16);
v4i32 __builtin_msa_mod_s_w (v4i32, v4i32);
v2i64 __builtin_msa_mod_s_d (v2i64, v2i64);

v16u8 __builtin_msa_mod_u_b (v16u8, v16u8);
v8u16 __builtin_msa_mod_u_h (v8u16, v8u16);
v4u32 __builtin_msa_mod_u_w (v4u32, v4u32);
v2u64 __builtin_msa_mod_u_d (v2u64, v2u64);

v16i8 __builtin_msa_move_v (v16i8);

v8i16 __builtin_msa_msub_q_h (v8i16, v8i16, v8i16);
```

```
v4i32 __builtin_msa_msub_q_w (v4i32, v4i32, v4i32);

v8i16 __builtin_msa_msubr_q_h (v8i16, v8i16, v8i16);
v4i32 __builtin_msa_msubr_q_w (v4i32, v4i32, v4i32);

v16i8 __builtin_msa_msubv_b (v16i8, v16i8, v16i8);
v8i16 __builtin_msa_msubv_h (v8i16, v8i16, v8i16);
v4i32 __builtin_msa_msubv_w (v4i32, v4i32, v4i32);
v2i64 __builtin_msa_msubv_d (v2i64, v2i64, v2i64);

v8i16 __builtin_msa_mul_q_h (v8i16, v8i16);
v4i32 __builtin_msa_mul_q_w (v4i32, v4i32);

v8i16 __builtin_msa_mulr_q_h (v8i16, v8i16);
v4i32 __builtin_msa_mulr_q_w (v4i32, v4i32);

v16i8 __builtin_msa_mulv_b (v16i8, v16i8);
v8i16 __builtin_msa_mulv_h (v8i16, v8i16);
v4i32 __builtin_msa_mulv_w (v4i32, v4i32);
v2i64 __builtin_msa_mulv_d (v2i64, v2i64);

v16i8 __builtin_msa_nloc_b (v16i8);
v8i16 __builtin_msa_nloc_h (v8i16);
v4i32 __builtin_msa_nloc_w (v4i32);
v2i64 __builtin_msa_nloc_d (v2i64);

v16i8 __builtin_msa_nlzc_b (v16i8);
v8i16 __builtin_msa_nlzc_h (v8i16);
v4i32 __builtin_msa_nlzc_w (v4i32);
v2i64 __builtin_msa_nlzc_d (v2i64);

v16u8 __builtin_msa_nor_v (v16u8, v16u8);

v16u8 __builtin_msa_nori_b (v16u8, imm0_255);

v16u8 __builtin_msa_or_v (v16u8, v16u8);

v16u8 __builtin_msa_ori_b (v16u8, imm0_255);

v16i8 __builtin_msa_pckev_b (v16i8, v16i8);
v8i16 __builtin_msa_pckev_h (v8i16, v8i16);
v4i32 __builtin_msa_pckev_w (v4i32, v4i32);
v2i64 __builtin_msa_pckev_d (v2i64, v2i64);

v16i8 __builtin_msa_pckod_b (v16i8, v16i8);
v8i16 __builtin_msa_pckod_h (v8i16, v8i16);
v4i32 __builtin_msa_pckod_w (v4i32, v4i32);
v2i64 __builtin_msa_pckod_d (v2i64, v2i64);

v16i8 __builtin_msa_pcnt_b (v16i8);
v8i16 __builtin_msa_pcnt_h (v8i16);
v4i32 __builtin_msa_pcnt_w (v4i32);
v2i64 __builtin_msa_pcnt_d (v2i64);

v16i8 __builtin_msa_sat_s_b (v16i8, imm0_7);
v8i16 __builtin_msa_sat_s_h (v8i16, imm0_15);
v4i32 __builtin_msa_sat_s_w (v4i32, imm0_31);
v2i64 __builtin_msa_sat_s_d (v2i64, imm0_63);
```

```
v16u8 __builtin_msa_sat_u_b (v16u8, imm0_7);
v8u16 __builtin_msa_sat_u_h (v8u16, imm0_15);
v4u32 __builtin_msa_sat_u_w (v4u32, imm0_31);
v2u64 __builtin_msa_sat_u_d (v2u64, imm0_63);

v16i8 __builtin_msa_shf_b (v16i8, imm0_255);
v8i16 __builtin_msa_shf_h (v8i16, imm0_255);
v4i32 __builtin_msa_shf_w (v4i32, imm0_255);

v16i8 __builtin_msa_sld_b (v16i8, v16i8, i32);
v8i16 __builtin_msa_sld_h (v8i16, v8i16, i32);
v4i32 __builtin_msa_sld_w (v4i32, v4i32, i32);
v2i64 __builtin_msa_sld_d (v2i64, v2i64, i32);

v16i8 __builtin_msa_sldi_b (v16i8, v16i8, imm0_15);
v8i16 __builtin_msa_sldi_h (v8i16, v8i16, imm0_7);
v4i32 __builtin_msa_sldi_w (v4i32, v4i32, imm0_3);
v2i64 __builtin_msa_sldi_d (v2i64, v2i64, imm0_1);

v16i8 __builtin_msa_sll_b (v16i8, v16i8);
v8i16 __builtin_msa_sll_h (v8i16, v8i16);
v4i32 __builtin_msa_sll_w (v4i32, v4i32);
v2i64 __builtin_msa_sll_d (v2i64, v2i64);

v16i8 __builtin_msa_slli_b (v16i8, imm0_7);
v8i16 __builtin_msa_slli_h (v8i16, imm0_15);
v4i32 __builtin_msa_slli_w (v4i32, imm0_31);
v2i64 __builtin_msa_slli_d (v2i64, imm0_63);

v16i8 __builtin_msa_splat_b (v16i8, i32);
v8i16 __builtin_msa_splat_h (v8i16, i32);
v4i32 __builtin_msa_splat_w (v4i32, i32);
v2i64 __builtin_msa_splat_d (v2i64, i32);

v16i8 __builtin_msa_splati_b (v16i8, imm0_15);
v8i16 __builtin_msa_splati_h (v8i16, imm0_7);
v4i32 __builtin_msa_splati_w (v4i32, imm0_3);
v2i64 __builtin_msa_splati_d (v2i64, imm0_1);

v16i8 __builtin_msa_sra_b (v16i8, v16i8);
v8i16 __builtin_msa_sra_h (v8i16, v8i16);
v4i32 __builtin_msa_sra_w (v4i32, v4i32);
v2i64 __builtin_msa_sra_d (v2i64, v2i64);

v16i8 __builtin_msa_srai_b (v16i8, imm0_7);
v8i16 __builtin_msa_srai_h (v8i16, imm0_15);
v4i32 __builtin_msa_srai_w (v4i32, imm0_31);
v2i64 __builtin_msa_srai_d (v2i64, imm0_63);

v16i8 __builtin_msa_srar_b (v16i8, v16i8);
v8i16 __builtin_msa_srar_h (v8i16, v8i16);
v4i32 __builtin_msa_srar_w (v4i32, v4i32);
v2i64 __builtin_msa_srar_d (v2i64, v2i64);

v16i8 __builtin_msa_srari_b (v16i8, imm0_7);
v8i16 __builtin_msa_srari_h (v8i16, imm0_15);
v4i32 __builtin_msa_srari_w (v4i32, imm0_31);
```

```
v2i64 __builtin_msa_srari_d (v2i64, imm0_63);

v16i8 __builtin_msa_srl_b (v16i8, v16i8);
v8i16 __builtin_msa_srl_h (v8i16, v8i16);
v4i32 __builtin_msa_srl_w (v4i32, v4i32);
v2i64 __builtin_msa_srl_d (v2i64, v2i64);

v16i8 __builtin_msa_srli_b (v16i8, imm0_7);
v8i16 __builtin_msa_srli_h (v8i16, imm0_15);
v4i32 __builtin_msa_srli_w (v4i32, imm0_31);
v2i64 __builtin_msa_srli_d (v2i64, imm0_63);

v16i8 __builtin_msa_srlr_b (v16i8, v16i8);
v8i16 __builtin_msa_srlr_h (v8i16, v8i16);
v4i32 __builtin_msa_srlr_w (v4i32, v4i32);
v2i64 __builtin_msa_srlr_d (v2i64, v2i64);

v16i8 __builtin_msa_srlri_b (v16i8, imm0_7);
v8i16 __builtin_msa_srlri_h (v8i16, imm0_15);
v4i32 __builtin_msa_srlri_w (v4i32, imm0_31);
v2i64 __builtin_msa_srlri_d (v2i64, imm0_63);

void __builtin_msa_st_b (v16i8, void *, imm_n512_511);
void __builtin_msa_st_h (v8i16, void *, imm_n1024_1022);
void __builtin_msa_st_w (v4i32, void *, imm_n2048_2044);
void __builtin_msa_st_d (v2i64, void *, imm_n4096_4088);

v16i8 __builtin_msa_subs_s_b (v16i8, v16i8);
v8i16 __builtin_msa_subs_s_h (v8i16, v8i16);
v4i32 __builtin_msa_subs_s_w (v4i32, v4i32);
v2i64 __builtin_msa_subs_s_d (v2i64, v2i64);

v16u8 __builtin_msa_subs_u_b (v16u8, v16u8);
v8u16 __builtin_msa_subs_u_h (v8u16, v8u16);
v4u32 __builtin_msa_subs_u_w (v4u32, v4u32);
v2u64 __builtin_msa_subs_u_d (v2u64, v2u64);

v16u8 __builtin_msa_subsus_u_b (v16u8, v16i8);
v8u16 __builtin_msa_subsus_u_h (v8u16, v8i16);
v4u32 __builtin_msa_subsus_u_w (v4u32, v4i32);
v2u64 __builtin_msa_subsus_u_d (v2u64, v2i64);

v16i8 __builtin_msa_subsuu_s_b (v16u8, v16u8);
v8i16 __builtin_msa_subsuu_s_h (v8u16, v8u16);
v4i32 __builtin_msa_subsuu_s_w (v4u32, v4u32);
v2i64 __builtin_msa_subsuu_s_d (v2u64, v2u64);

v16i8 __builtin_msa_subv_b (v16i8, v16i8);
v8i16 __builtin_msa_subv_h (v8i16, v8i16);
v4i32 __builtin_msa_subv_w (v4i32, v4i32);
v2i64 __builtin_msa_subv_d (v2i64, v2i64);

v16i8 __builtin_msa_subvi_b (v16i8, imm0_31);
v8i16 __builtin_msa_subvi_h (v8i16, imm0_31);
v4i32 __builtin_msa_subvi_w (v4i32, imm0_31);
v2i64 __builtin_msa_subvi_d (v2i64, imm0_31);

v16i8 __builtin_msa_vshf_b (v16i8, v16i8, v16i8);
```

```
v8i16 __builtin_msa_vshf_h (v8i16, v8i16, v8i16);
v4i32 __builtin_msa_vshf_w (v4i32, v4i32, v4i32);
v2i64 __builtin_msa_vshf_d (v2i64, v2i64, v2i64);

v16u8 __builtin_msa_xor_v (v16u8, v16u8);

v16u8 __builtin_msa_xori_b (v16u8, imm0_255);
```

7.13.19 Other MIPS Built-in Functions

GCC provides other MIPS-specific built-in functions:

`void __builtin_mips_cache (int op, const volatile void *addr)`
: Insert a '`cache`' instruction with operands *op* and *addr*. GCC defines the preprocessor macro `___GCC_HAVE_BUILTIN_MIPS_CACHE` when this function is available.

`unsigned int __builtin_mips_get_fcsr (void)`
`void __builtin_mips_set_fcsr (unsigned int value)`
: Get and set the contents of the floating-point control and status register (FPU control register 31). These functions are only available in hard-float code but can be called in both MIPS16 and non-MIPS16 contexts.

  `__builtin_mips_set_fcsr` can be used to change any bit of the register except the condition codes, which GCC assumes are preserved.

7.13.20 MSP430 Built-in Functions

GCC provides a couple of special builtin functions to aid in the writing of interrupt handlers in C.

`__bic_SR_register_on_exit (int mask)`
: This clears the indicated bits in the saved copy of the status register currently residing on the stack. This only works inside interrupt handlers and the changes to the status register will only take affect once the handler returns.

`__bis_SR_register_on_exit (int mask)`
: This sets the indicated bits in the saved copy of the status register currently residing on the stack. This only works inside interrupt handlers and the changes to the status register will only take affect once the handler returns.

`__delay_cycles (long long cycles)`
: This inserts an instruction sequence that takes exactly *cycles* cycles (between 0 and about 17E9) to complete. The inserted sequence may use jumps, loops, or no-ops, and does not interfere with any other instructions. Note that *cycles* must be a compile-time constant integer - that is, you must pass a number, not a variable that may be optimized to a constant later. The number of cycles delayed by this builtin is exact.

7.13.21 NDS32 Built-in Functions

These built-in functions are available for the NDS32 target:

`void __builtin_nds32_isync (int *addr)` [Built-in Function]
: Insert an ISYNC instruction into the instruction stream where *addr* is an instruction address for serialization.

`void __builtin_nds32_isb (void)` [Built-in Function]
Insert an ISB instruction into the instruction stream.

`int __builtin_nds32_mfsr (int sr)` [Built-in Function]
Return the content of a system register which is mapped by *sr*.

`int __builtin_nds32_mfusr (int usr)` [Built-in Function]
Return the content of a user space register which is mapped by *usr*.

`void __builtin_nds32_mtsr (int value, int sr)` [Built-in Function]
Move the *value* to a system register which is mapped by *sr*.

`void __builtin_nds32_mtusr (int value, int usr)` [Built-in Function]
Move the *value* to a user space register which is mapped by *usr*.

`void __builtin_nds32_setgie_en (void)` [Built-in Function]
Enable global interrupt.

`void __builtin_nds32_setgie_dis (void)` [Built-in Function]
Disable global interrupt.

7.13.22 Nvidia PTX Built-in Functions

These built-in functions are available for the Nvidia PTX target:

`unsigned int __builtin_nvptx_brev (unsigned int x)` [Built-in Function]
Reverse the bit order of a 32-bit unsigned integer.

`unsigned long long __builtin_nvptx_brevll (unsigned long long x)` [Built-in Function]
Reverse the bit order of a 64-bit unsigned integer.

7.13.23 Basic PowerPC Built-in Functions

This section describes PowerPC built-in functions that do not require the inclusion of any special header files to declare prototypes or provide macro definitions. The sections that follow describe additional PowerPC built-in functions.

7.13.23.1 Basic PowerPC Built-in Functions Available on all Configurations

`void __builtin_cpu_init (void)` [Built-in Function]
This function is a `nop` on the PowerPC platform and is included solely to maintain API compatibility with the x86 builtins.

`int __builtin_cpu_is (const char *cpuname)` [Built-in Function]
This function returns a value of `1` if the run-time CPU is of type *cpuname* and returns `0` otherwise

The `__builtin_cpu_is` function requires GLIBC 2.23 or newer which exports the hardware capability bits. GCC defines the macro `__BUILTIN_CPU_SUPPORTS__` if the `__builtin_cpu_supports` built-in function is fully supported.

If GCC was configured to use a GLIBC before 2.23, the built-in function `__builtin_cpu_is` always returns a 0 and the compiler issues a warning.

The following CPU names can be detected:

'power10' IBM POWER10 Server CPU.

'power9' IBM POWER9 Server CPU.

'power8' IBM POWER8 Server CPU.

'power7' IBM POWER7 Server CPU.

'power6x' IBM POWER6 Server CPU (RAW mode).

'power6' IBM POWER6 Server CPU (Architected mode).

'power5+' IBM POWER5+ Server CPU.

'power5' IBM POWER5 Server CPU.

'ppc970' IBM 970 Server CPU (ie, Apple G5).

'power4' IBM POWER4 Server CPU.

'ppca2' IBM A2 64-bit Embedded CPU

'ppc476' IBM PowerPC 476FP 32-bit Embedded CPU.

'ppc464' IBM PowerPC 464 32-bit Embedded CPU.

'ppc440' PowerPC 440 32-bit Embedded CPU.

'ppc405' PowerPC 405 32-bit Embedded CPU.

'ppc-cell-be'
IBM PowerPC Cell Broadband Engine Architecture CPU.

Here is an example:

```
#ifdef __BUILTIN_CPU_SUPPORTS__
  if (__builtin_cpu_is ("power8"))
    {
       do_power8 (); // POWER8 specific implementation.
    }
  else
#endif
    {
       do_generic (); // Generic implementation.
    }
```

`int __builtin_cpu_supports (const char *feature)` [Built-in Function]

This function returns a value of `1` if the run-time CPU supports the HWCAP feature *feature* and returns `0` otherwise.

The `__builtin_cpu_supports` function requires GLIBC 2.23 or newer which exports the hardware capability bits. GCC defines the macro `__BUILTIN_CPU_SUPPORTS__` if the `__builtin_cpu_supports` built-in function is fully supported.

If GCC was configured to use a GLIBC before 2.23, the built-in function `__builtin_cpu_supports` always returns a 0 and the compiler issues a warning.

The following features can be detected:

'4xxmac' 4xx CPU has a Multiply Accumulator.

'altivec' CPU has a SIMD/Vector Unit.

'arch_2_05'
: CPU supports ISA 2.05 (eg, POWER6)

'arch_2_06'
: CPU supports ISA 2.06 (eg, POWER7)

'arch_2_07'
: CPU supports ISA 2.07 (eg, POWER8)

'arch_3_00'
: CPU supports ISA 3.0 (eg, POWER9)

'arch_3_1'
: CPU supports ISA 3.1 (eg, POWER10)

'archpmu' CPU supports the set of compatible performance monitoring events.

'booke' CPU supports the Embedded ISA category.

'cellbe' CPU has a CELL broadband engine.

'darn' CPU supports the `darn` (deliver a random number) instruction.

'dfp' CPU has a decimal floating point unit.

'dscr' CPU supports the data stream control register.

'ebb' CPU supports event base branching.

'efpdouble'
: CPU has a SPE double precision floating point unit.

'efpsingle'
: CPU has a SPE single precision floating point unit.

'fpu' CPU has a floating point unit.

'htm' CPU has hardware transaction memory instructions.

'htm-nosc'
: Kernel aborts hardware transactions when a syscall is made.

'htm-no-suspend'
: CPU supports hardware transaction memory but does not support the `tsuspend.` instruction.

'ic_snoop'
: CPU supports icache snooping capabilities.

'ieee128' CPU supports 128-bit IEEE binary floating point instructions.

'isel' CPU supports the integer select instruction.

'mma' CPU supports the matrix-multiply assist instructions.

'mmu' CPU has a memory management unit.

'notb' CPU does not have a timebase (eg, 601 and 403gx).

'pa6t' CPU supports the PA Semi 6T CORE ISA.

'power4' CPU supports ISA 2.00 (eg, POWER4)

'power5' CPU supports ISA 2.02 (eg, POWER5)

'power5+' CPU supports ISA 2.03 (eg, POWER5+)

'power6x' CPU supports ISA 2.05 (eg, POWER6) extended opcodes mffgpr and mftgpr.

'ppc32' CPU supports 32-bit mode execution.

'ppc601' CPU supports the old POWER ISA (eg, 601)

'ppc64' CPU supports 64-bit mode execution.

'ppcle' CPU supports a little-endian mode that uses address swizzling.

'scv' Kernel supports system call vectored.

'smt' CPU support simultaneous multi-threading.

'spe' CPU has a signal processing extension unit.

'tar' CPU supports the target address register.

'true_le' CPU supports true little-endian mode.

'ucache' CPU has unified I/D cache.

'vcrypto' CPU supports the vector cryptography instructions.

'vsx' CPU supports the vector-scalar extension.

Here is an example:

```
#ifdef __BUILTIN_CPU_SUPPORTS__
  if (__builtin_cpu_supports ("fpu"))
    {
       asm("fadd %0,%1,%2" : "=d"(dst) : "d"(src1), "d"(src2));
    }
  else
#endif
    {
       dst = __fadd (src1, src2); // Software FP addition function.
    }
```

The following built-in functions are also available on all PowerPC processors:

```
uint64_t __builtin_ppc_get_timebase ();
unsigned long __builtin_ppc_mftb ();
double __builtin_unpack_ibm128 (__ibm128, int);
__ibm128 __builtin_pack_ibm128 (double, double);
double __builtin_mffs (void);
void __builtin_mtfsf (const int, double);
void __builtin_mtfsb0 (const int);
void __builtin_mtfsb1 (const int);
double __builtin_set_fpscr_rn (int);
```

The `__builtin_ppc_get_timebase` and `__builtin_ppc_mftb` functions generate instructions to read the Time Base Register. The `__builtin_ppc_get_timebase` function may generate multiple instructions and always returns the 64 bits of the Time Base

Register. The `__builtin_ppc_mftb` function always generates one instruction and returns the Time Base Register value as an unsigned long, throwing away the most significant word on 32-bit environments. The `__builtin_mffs` return the value of the FPSCR register. Note, ISA 3.0 supports the `__builtin_mffsl()` which permits software to read the control and non-sticky status bits in the FSPCR without the higher latency associated with accessing the sticky status bits. The `__builtin_mtfsf` takes a constant 8-bit integer field mask and a double precision floating point argument and generates the `mtfsf` (extended mnemonic) instruction to write new values to selected fields of the FPSCR. The `__builtin_mtfsb0` and `__builtin_mtfsb1` take the bit to change as an argument. The valid bit range is between 0 and 31. The builtins map to the `mtfsb0` and `mtfsb1` instructions which take the argument and add 32. Hence these instructions only modify the FPSCR[32:63] bits by changing the specified bit to a zero or one respectively.

The `__builtin_set_fpscr_rn` built-in allows changing both of the floating point rounding mode bits and returning the various FPSCR fields before the RN field is updated. The built-in returns a double consisting of the initial value of the FPSCR fields DRN, VE, OE, UE, ZE, XE, NI, and RN bit positions with all other bits set to zero. The built-in argument is a 2-bit value for the new RN field value. The argument can either be an `const int` or stored in a variable. Earlier versions of `__builtin_set_fpscr_rn` returned void. A `__SET_FPSCR_RN_RETURNS_FPSCR__` macro has been added. If defined, then the `__builtin_set_fpscr_rn` built-in returns the FPSCR fields. If not defined, the `__builtin_set_fpscr_rn` does not return a value. If the `-msoft-float` option is used, the `__builtin_set_fpscr_rn` built-in will not return a value.

7.13.23.2 Basic PowerPC Built-in Functions Available on ISA 2.05

The basic built-in functions described in this section are available on the PowerPC family of processors starting with ISA 2.05 or later. Unless specific options are explicitly disabled on the command line, specifying option `-mcpu=power6` has the effect of enabling the `-mpowerpc64`, `-mpowerpc-gpopt`, `-mpowerpc-gfxopt`, `-mmfcrf`, `-mpopcntb`, `-mfprnd`, `-mcmpb`, `-mhard-dfp`, and `-mrecip-precision` options. Specify the `-maltivec` option explicitly in combination with the above options if desired.

The following functions require option `-mcmpb`.

```
unsigned long long __builtin_cmpb (unsigned long long int, unsigned long long int);
unsigned int __builtin_cmpb (unsigned int, unsigned int);
```

The `__builtin_cmpb` function performs a byte-wise compare on the contents of its two arguments, returning the result of the byte-wise comparison as the returned value. For each byte comparison, the corresponding byte of the return value holds 0xff if the input bytes are equal and 0 if the input bytes are not equal. If either of the arguments to this built-in function is wider than 32 bits, the function call expands into the form that expects `unsigned long long int` arguments which is only available on 64-bit targets.

The following built-in functions are available when hardware decimal floating point (`-mhard-dfp`) is available:

```
void __builtin_set_fpscr_drn(int);
_Decimal64 __builtin_ddedpd (int, _Decimal64);
_Decimal128 __builtin_ddedpdq (int, _Decimal128);
_Decimal64 __builtin_denbcd (int, _Decimal64);
_Decimal128 __builtin_denbcdq (int, _Decimal128);
_Decimal64 __builtin_diex (long long, _Decimal64);
```

```
_Decimal128 _builtin_diexq (long long, _Decimal128);
_Decimal64 __builtin_dscli (_Decimal64, int);
_Decimal128 __builtin_dscliq (_Decimal128, int);
_Decimal64 __builtin_dscri (_Decimal64, int);
_Decimal128 __builtin_dscriq (_Decimal128, int);
long long __builtin_dxex (_Decimal64);
long long __builtin_dxexq (_Decimal128);
_Decimal128 __builtin_pack_dec128 (unsigned long long, unsigned long long);
unsigned long long __builtin_unpack_dec128 (_Decimal128, int);

The __builtin_set_fpscr_drn builtin allows changing the three decimal
floating point rounding mode bits.  The argument is a 3-bit value.  The
argument can either be a const int or the value can be stored in
a variable.
The builtin uses the ISA 3.0 instruction mffscdrn if available.
Otherwise the builtin reads the FPSCR, masks the current decimal rounding
mode bits out and OR's in the new value.

_Decimal64 __builtin_dfp_quantize (_Decimal64, _Decimal64, const int);
_Decimal64 __builtin_dfp_quantize (const int, _Decimal64, const int);
_Decimal128 __builtin_dfp_quantize (_Decimal128, _Decimal128, const int);
_Decimal128 __builtin_dfp_quantize (const int, _Decimal128, const int);

The __builtin_dfp_quantize built-in, converts and rounds the second
argument to the form with the exponent as specified by the first
argument based on the rounding mode specified by the third argument.
If the first argument is a decimal floating point value, its exponent is used
for converting and rounding of the second argument.  If the first argument is a
5-bit constant integer value, then the value specifies the exponent to be used
when rounding and converting the second argument.  The third argument is a
two bit constant integer that specifies the rounding mode.  The possible modes
are: 00 Round to nearest, ties to even; 01 Round toward 0; 10 Round to nearest,
ties away from 0; 11 Round according to DRN where DRN is the Decimal Floating
point field of the FPSCR.
```

The following functions require `-mhard-float`, `-mpowerpc-gfxopt`, and `-mpopcntb` options.

```
double __builtin_recipdiv (double, double);
float __builtin_recipdivf (float, float);
double __builtin_rsqrt (double);
float __builtin_rsqrtf (float);
```

The `vec_rsqrt`, `__builtin_rsqrt`, and `__builtin_rsqrtf` functions generate multiple instructions to implement the reciprocal sqrt functionality using reciprocal sqrt estimate instructions.

The `__builtin_recipdiv`, and `__builtin_recipdivf` functions generate multiple instructions to implement division using the reciprocal estimate instructions.

The following functions require `-mhard-float` and `-mmultiple` options.

The `__builtin_unpack_longdouble` function takes a `long double` argument and a compile time constant of 0 or 1. If the constant is 0, the first `double` within the `long double` is returned, otherwise the second `double` is returned. The `__builtin_unpack_longdouble` function is only available if `long double` uses the IBM extended double representation.

The `__builtin_pack_longdouble` function takes two `double` arguments and returns a `long double` value that combines the two arguments. The `__builtin_pack_longdouble` function is only available if `long double` uses the IBM extended double representation.

The `__builtin_unpack_ibm128` function takes a `__ibm128` argument and a compile time constant of 0 or 1. If the constant is 0, the first `double` within the `__ibm128` is returned, otherwise the second `double` is returned.

The `__builtin_pack_ibm128` function takes two `double` arguments and returns a `__ibm128` value that combines the two arguments.

Additional built-in functions are available for the 64-bit PowerPC family of processors, for efficient use of 128-bit floating point (`__float128`) values.

Vector select

```
vector signed __int128 vec_sel (vector signed __int128,
               vector signed __int128, vector bool __int128);
vector signed __int128 vec_sel (vector signed __int128,
               vector signed __int128, vector unsigned __int128);
vector unsigned __int128 vec_sel (vector unsigned __int128,
               vector unsigned __int128, vector bool __int128);
vector unsigned __int128 vec_sel (vector unsigned __int128,
               vector unsigned __int128, vector unsigned __int128);
vector bool __int128 vec_sel (vector bool __int128,
               vector bool __int128, vector bool __int128);
vector bool __int128 vec_sel (vector bool __int128,
               vector bool __int128, vector unsigned __int128);
```

The instance is an extension of the existing overloaded built-in `vec_sel` that is documented in the PVIPR.

```
vector signed __int128 vec_perm (vector signed __int128,
               vector signed __int128);
vector unsigned __int128 vec_perm (vector unsigned __int128,
               vector unsigned __int128);
```

The instance is an extension of the existing overloaded built-in `vec_perm` that is documented in the PVIPR.

7.13.23.3 Basic PowerPC Built-in Functions Available on ISA 2.06

The basic built-in functions described in this section are available on the PowerPC family of processors starting with ISA 2.05 or later. Unless specific options are explicitly disabled on the command line, specifying option `-mcpu=power7` has the effect of enabling all the same options as for `-mcpu=power6` in addition to the `-maltivec`, `-mpopcntd`, and `-mvsx` options.

The following basic built-in functions require `-mpopcntd`:

```
unsigned int __builtin_addg6s (unsigned int, unsigned int);
long long __builtin_bpermd (long long, long long);
unsigned int __builtin_cbcdtd (unsigned int);
unsigned int __builtin_cdtbcd (unsigned int);
long long __builtin_divde (long long, long long);
unsigned long long __builtin_divdeu (unsigned long long, unsigned long long);
int __builtin_divwe (int, int);
unsigned int __builtin_divweu (unsigned int, unsigned int);
vector __int128 __builtin_pack_vector_int128 (long long, long long);
void __builtin_rs6000_speculation_barrier (void);
long long __builtin_unpack_vector_int128 (vector __int128, signed char);
```

Of these, the `__builtin_divde` and `__builtin_divdeu` functions require a 64-bit environment.

The following basic built-in functions, which are also supported on x86 targets, require `-mfloat128`.

```
__float128 __builtin_fabsq (__float128);
__float128 __builtin_copysignq (__float128, __float128);
__float128 __builtin_infq (void);
__float128 __builtin_huge_valq (void);
__float128 __builtin_nanq (void);
__float128 __builtin_nansq (void);

__float128 __builtin_sqrtf128 (__float128);
__float128 __builtin_fmaf128 (__float128, __float128, __float128);
```

7.13.23.4 Basic PowerPC Built-in Functions Available on ISA 2.07

The basic built-in functions described in this section are available on the PowerPC family of processors starting with ISA 2.07 or later. Unless specific options are explicitly disabled on the command line, specifying option `-mcpu=power8` has the effect of enabling all the same options as for `-mcpu=power7` in addition to the `-mpower8-fusion`, `-mcrypto`, `-mhtm`, `-mquad-memory`, and `-mquad-memory-atomic` options.

This section intentionally empty.

7.13.23.5 Basic PowerPC Built-in Functions Available on ISA 3.0

The basic built-in functions described in this section are available on the PowerPC family of processors starting with ISA 3.0 or later. Unless specific options are explicitly disabled on the command line, specifying option `-mcpu=power9` has the effect of enabling all the same options as for `-mcpu=power8` in addition to the `-misel` option.

The following built-in functions are available on Linux 64-bit systems that use the ISA 3.0 instruction set (`-mcpu=power9`):

`__float128 __builtin_addf128_round_to_odd (__float128, __float128)` [Built-in Function]

Perform a 128-bit IEEE floating point add using round to odd as the rounding mode.

`__float128 __builtin_subf128_round_to_odd (__float128, __float128)` [Built-in Function]

Perform a 128-bit IEEE floating point subtract using round to odd as the rounding mode.

`__float128 __builtin_mulf128_round_to_odd (__float128, __float128)` [Built-in Function]

Perform a 128-bit IEEE floating point multiply using round to odd as the rounding mode.

`__float128 __builtin_divf128_round_to_odd (__float128, __float128)` [Built-in Function]

Perform a 128-bit IEEE floating point divide using round to odd as the rounding mode.

`__float128 __builtin_sqrtf128_round_to_odd (__float128)` [Built-in Function]
: Perform a 128-bit IEEE floating point square root using round to odd as the rounding mode.

`__float128 __builtin_fmaf128_round_to_odd (__float128, __float128, __float128)` [Built-in Function]
: Perform a 128-bit IEEE floating point fused multiply and add operation using round to odd as the rounding mode.

`double __builtin_truncf128_round_to_odd (__float128)` [Built-in Function]
: Convert a 128-bit IEEE floating point value to `double` using round to odd as the rounding mode.

The following additional built-in functions are also available for the PowerPC family of processors, starting with ISA 3.0 or later:

`long long __builtin_darn (void)` [Built-in Function]
`long long __builtin_darn_raw (void)` [Built-in Function]
`int __builtin_darn_32 (void)` [Built-in Function]
: The `__builtin_darn` and `__builtin_darn_raw` functions require a 64-bit environment supporting ISA 3.0 or later. The `__builtin_darn` function provides a 64-bit conditioned random number. The `__builtin_darn_raw` function provides a 64-bit raw random number. The `__builtin_darn_32` function provides a 32-bit conditioned random number.

The following additional built-in functions are also available for the PowerPC family of processors, starting with ISA 3.0 or later:

```
int __builtin_byte_in_set (unsigned char u, unsigned long long set);
int __builtin_byte_in_range (unsigned char u, unsigned int range);
int __builtin_byte_in_either_range (unsigned char u, unsigned int ranges);

int __builtin_dfp_dtstsfi_lt (unsigned int comparison, _Decimal64 value);
int __builtin_dfp_dtstsfi_lt (unsigned int comparison, _Decimal128 value);
int __builtin_dfp_dtstsfi_lt_dd (unsigned int comparison, _Decimal64 value);
int __builtin_dfp_dtstsfi_lt_td (unsigned int comparison, _Decimal128 value);

int __builtin_dfp_dtstsfi_gt (unsigned int comparison, _Decimal64 value);
int __builtin_dfp_dtstsfi_gt (unsigned int comparison, _Decimal128 value);
int __builtin_dfp_dtstsfi_gt_dd (unsigned int comparison, _Decimal64 value);
int __builtin_dfp_dtstsfi_gt_td (unsigned int comparison, _Decimal128 value);

int __builtin_dfp_dtstsfi_eq (unsigned int comparison, _Decimal64 value);
int __builtin_dfp_dtstsfi_eq (unsigned int comparison, _Decimal128 value);
int __builtin_dfp_dtstsfi_eq_dd (unsigned int comparison, _Decimal64 value);
int __builtin_dfp_dtstsfi_eq_td (unsigned int comparison, _Decimal128 value);

int __builtin_dfp_dtstsfi_ov (unsigned int comparison, _Decimal64 value);
int __builtin_dfp_dtstsfi_ov (unsigned int comparison, _Decimal128 value);
int __builtin_dfp_dtstsfi_ov_dd (unsigned int comparison, _Decimal64 value);
int __builtin_dfp_dtstsfi_ov_td (unsigned int comparison, _Decimal128 value);

double __builtin_mffsl(void);
```

The `__builtin_byte_in_set` function requires a 64-bit environment supporting ISA 3.0 or later. This function returns a non-zero value if and only if its `u` argument exactly equals one of the eight bytes contained within its 64-bit `set` argument.

The `__builtin_byte_in_range` and `__builtin_byte_in_either_range` require an environment supporting ISA 3.0 or later. For these two functions, the `range` argument is encoded as 4 bytes, organized as `hi_1:lo_1:hi_2:lo_2`. The `__builtin_byte_in_range` function returns a non-zero value if and only if its `u` argument is within the range bounded between `lo_2` and `hi_2` inclusive. The `__builtin_byte_in_either_range` function returns non-zero if and only if its `u` argument is within either the range bounded between `lo_1` and `hi_1` inclusive or the range bounded between `lo_2` and `hi_2` inclusive.

The `__builtin_dfp_dtstsfi_lt` function returns a non-zero value if and only if the number of significant digits of its `value` argument is less than its `comparison` argument. The `__builtin_dfp_dtstsfi_lt_dd` and `__builtin_dfp_dtstsfi_lt_td` functions behave similarly, but require that the type of the `value` argument be `__Decimal64` and `__Decimal128` respectively.

The `__builtin_dfp_dtstsfi_gt` function returns a non-zero value if and only if the number of significant digits of its `value` argument is greater than its `comparison` argument. The `__builtin_dfp_dtstsfi_gt_dd` and `__builtin_dfp_dtstsfi_gt_td` functions behave similarly, but require that the type of the `value` argument be `__Decimal64` and `__Decimal128` respectively.

The `__builtin_dfp_dtstsfi_eq` function returns a non-zero value if and only if the number of significant digits of its `value` argument equals its `comparison` argument. The `__builtin_dfp_dtstsfi_eq_dd` and `__builtin_dfp_dtstsfi_eq_td` functions behave similarly, but require that the type of the `value` argument be `__Decimal64` and `__Decimal128` respectively.

The `__builtin_dfp_dtstsfi_ov` function returns a non-zero value if and only if its `value` argument has an undefined number of significant digits, such as when `value` is an encoding of `NaN`. The `__builtin_dfp_dtstsfi_ov_dd` and `__builtin_dfp_dtstsfi_ov_td` functions behave similarly, but require that the type of the `value` argument be `__Decimal64` and `__Decimal128` respectively.

The `__builtin_mffsl` uses the ISA 3.0 `mffsl` instruction to read the FPSCR. The instruction is a lower latency version of the `mffs` instruction. If the `mffsl` instruction is not available, then the builtin uses the older `mffs` instruction to read the FPSCR.

7.13.23.6 Basic PowerPC Built-in Functions Available on ISA 3.1

The basic built-in functions described in this section are available on the PowerPC family of processors starting with ISA 3.1. Unless specific options are explicitly disabled on the command line, specifying option `-mcpu=power10` has the effect of enabling all the same options as for `-mcpu=power9`.

The following built-in functions are available on Linux 64-bit systems that use a future architecture instruction set (`-mcpu=power10`):

`unsigned long long __builtin_cfuged (unsigned long long, unsigned long long)` [Built-in Function]

Perform a 64-bit centrifuge operation, as if implemented by the `cfuged` instruction.

unsigned long long __builtin_cntlzdm (unsigned long long, unsigned long long) [Built-in Function]

Perform a 64-bit count leading zeros operation under mask, as if implemented by the cntlzdm instruction.

unsigned long long __builtin_cnttzdm (unsigned long long, unsigned long long) [Built-in Function]

Perform a 64-bit count trailing zeros operation under mask, as if implemented by the cnttzdm instruction.

unsigned long long __builtin_pdepd (unsigned long long, unsigned long long) [Built-in Function]

Perform a 64-bit parallel bits deposit operation, as if implemented by the pdepd instruction.

unsigned long long __builtin_pextd (unsigned long long, unsigned long long) [Built-in Function]

Perform a 64-bit parallel bits extract operation, as if implemented by the pextd instruction.

vector signed __int128 vsx_xl_sext (signed long long, signed char *) [Built-in Function]
vector signed __int128 vsx_xl_sext (signed long long, signed short *) [Built-in Function]
vector signed __int128 vsx_xl_sext (signed long long, signed int *) [Built-in Function]
vector signed __int128 vsx_xl_sext (signed long long, signed long long *) [Built-in Function]
vector unsigned __int128 vsx_xl_zext (signed long long, unsigned char *) [Built-in Function]
vector unsigned __int128 vsx_xl_zext (signed long long, unsigned short *) [Built-in Function]
vector unsigned __int128 vsx_xl_zext (signed long long, unsigned int *) [Built-in Function]
vector unsigned __int128 vsx_xl_zext (signed long long, unsigned long long *) [Built-in Function]

Load (and sign extend) to an __int128 vector, as if implemented by the ISA 3.1 lxvrbx, lxvrhx, lxvrwx, and lxvrdx instructions.

void vec_xst_trunc (vector signed __int128, signed long long, signed char *) [Built-in Function]
void vec_xst_trunc (vector signed __int128, signed long long, signed short *) [Built-in Function]
void vec_xst_trunc (vector signed __int128, signed long long, signed int *) [Built-in Function]
void vec_xst_trunc (vector signed __int128, signed long long, signed long long *) [Built-in Function]
void vec_xst_trunc (vector unsigned __int128, signed long long, unsigned char *) [Built-in Function]

void vec_xst_trunc (vector unsigned __int128, signed long long, unsigned short *) [Built-in Function]
void vec_xst_trunc (vector unsigned __int128, signed long long, unsigned int *) [Built-in Function]
void vec_xst_trunc (vector unsigned __int128, signed long long, unsigned long long *) [Built-in Function]

Truncate and store the rightmost element of a vector, as if implemented by the ISA 3.1 stxvrbx, stxvrhx, stxvrwx, and stxvrdx instructions.

7.13.24 PowerPC AltiVec/VSX Built-in Functions

GCC provides an interface for the PowerPC family of processors to access the AltiVec operations described in Motorola's AltiVec Programming Interface Manual. The interface is made available by including <altivec.h> and using -maltivec and -mabi=altivec. The interface supports the following vector types.

```
vector unsigned char
vector signed char
vector bool char

vector unsigned short
vector signed short
vector bool short
vector pixel

vector unsigned int
vector signed int
vector bool int
vector float
```

GCC's implementation of the high-level language interface available from C and C++ code differs from Motorola's documentation in several ways.

- A vector constant is a list of constant expressions within curly braces.
- A vector initializer requires no cast if the vector constant is of the same type as the variable it is initializing.
- If signed or unsigned is omitted, the signedness of the vector type is the default signedness of the base type. The default varies depending on the operating system, so a portable program should always specify the signedness.
- Compiling with -maltivec adds keywords __vector, vector, __pixel, pixel, __bool and bool. When compiling ISO C, the context-sensitive substitution of the keywords vector, pixel and bool is disabled. To use them, you must include <altivec.h> instead.
- GCC allows using a typedef name as the type specifier for a vector type, but only under the following circumstances:
  - When using __vector instead of vector; for example,

    ```
    typedef signed short int16;
    __vector int16 data;
    ```

  - When using vector in keyword-and-predefine mode; for example,

    ```
    typedef signed short int16;
    vector int16 data;
    ```

Note that keyword-and-predefine mode is enabled by disabling GNU extensions (e.g., by using `-std=c11`) and including `<altivec.h>`.

- For C, overloaded functions are implemented with macros so the following does not work:

  ```
  vec_add ((vector signed int){1, 2, 3, 4}, foo);
  ```

  Since `vec_add` is a macro, the vector constant in the example is treated as four separate arguments. Wrap the entire argument in parentheses for this to work.

Note: Only the `<altivec.h>` interface is supported. Internally, GCC uses built-in functions to achieve the functionality in the aforementioned header file, but they are not supported and are subject to change without notice.

GCC complies with the Power Vector Intrinsic Programming Reference (PVIPR), which may be found at `https://openpowerfoundation.org/?resource_lib=power-vector-intrinsic-programming-reference`. Chapter 4 of this document fully documents the vector API interfaces that must be provided by compliant compilers. Programmers should preferentially use the interfaces described therein. However, historically GCC has provided additional interfaces for access to vector instructions. These are briefly described below. Where the PVIPR provides a portable interface, other functions in GCC that provide the same capabilities should be considered deprecated.

The PVIPR documents the following overloaded functions:

vec_abs	vec_absd	vec_abss
vec_add	vec_addc	vec_adde
vec_addec	vec_adds	vec_all_eq
vec_all_ge	vec_all_gt	vec_all_in
vec_all_le	vec_all_lt	vec_all_nan
vec_all_ne	vec_all_nge	vec_all_ngt
vec_all_nle	vec_all_nlt	vec_all_numeric
vec_and	vec_andc	vec_any_eq
vec_any_ge	vec_any_gt	vec_any_le
vec_any_lt	vec_any_nan	vec_any_ne
vec_any_nge	vec_any_ngt	vec_any_nle
vec_any_nlt	vec_any_numeric	vec_any_out
vec_avg	vec_bperm	vec_ceil
vec_cipher_be	vec_cipherlast_be	vec_cmpb
vec_cmpeq	vec_cmpge	vec_cmpgt
vec_cmple	vec_cmplt	vec_cmpne
vec_cmpnez	vec_cntlz	vec_cntlz_lsbb
vec_cnttz	vec_cnttz_lsbb	vec_cpsgn
vec_ctf	vec_cts	vec_ctu
vec_div	vec_double	vec_doublee
vec_doubleh	vec_doublel	vec_doubleo
vec_eqv	vec_expte	vec_extract
vec_extract_exp	vec_extract_fp32_from_shorth	vec_extract_fp32_from_shortl

vec_extract_sig	vec_extract_4b	vec_first_match_index
vec_first_match_or_eos_index	vec_first_mismatch_index	vec_first_mismatch_or_eos_index
vec_float	vec_float2	vec_floate
vec_floato	vec_floor	vec_gb
vec_insert	vec_insert_exp	vec_insert4b
vec_ld	vec_lde	vec_ldl
vec_loge	vec_madd	vec_madds
vec_max	vec_mergee	vec_mergeh
vec_mergel	vec_mergeo	vec_mfvscr
vec_min	vec_mradds	vec_msub
vec_msum	vec_msums	vec_mtvscr
vec_mul	vec_mule	vec_mulo
vec_nabs	vec_nand	vec_ncipher_be
vec_ncipherlast_be	vec_nearbyint	vec_neg
vec_nmadd	vec_nmsub	vec_nor
vec_or	vec_orc	vec_pack
vec_pack_to_short_fp32	vec_packpx	vec_packs
vec_packsu	vec_parity_lsbb	vec_perm
vec_permxor	vec_pmsum_be	vec_popcnt
vec_re	vec_recipdiv	vec_revb
vec_reve	vec_rint	vec_rl
vec_rlmi	vec_rlnm	vec_round
vec_rsqrt	vec_rsqrte	vec_sbox_be
vec_sel	vec_shasigma_be	vec_signed
vec_signed2	vec_signede	vec_signedo
vec_sl	vec_sld	vec_sldw
vec_sll	vec_slo	vec_slv
vec_splat	vec_splat_s8	vec_splat_s16
vec_splat_s32	vec_splat_u8	vec_splat_u16
vec_splat_u32	vec_splats	vec_sqrt
vec_sr	vec_sra	vec_srl
vec_sro	vec_srv	vec_st
vec_ste	vec_stl	vec_sub
vec_subc	vec_sube	vec_subec
vec_subs	vec_sum2s	vec_sum4s
vec_sums	vec_test_data_class	vec_trunc
vec_unpackh	vec_unpackl	vec_unsigned
vec_unsigned2	vec_unsignede	vec_unsignedo
vec_xl	vec_xl_be	vec_xl_len
vec_xl_len_r	vec_xor	vec_xst
vec_xst_be	vec_xst_len	vec_xst_len_r

7.13.24.1 PowerPC AltiVec Built-in Functions on ISA 2.05

The following interfaces are supported for the generic and specific AltiVec operations and the AltiVec predicates. In cases where there is a direct mapping between generic and specific operations, only the generic names are shown here, although the specific operations can also be used.

Arguments that are documented as `const int` require literal integral values within the range required for that operation.

Only functions excluded from the PVIPR are listed here.

```
void vec_dss (const int);

void vec_dssall (void);

void vec_dst (const vector unsigned char *, int, const int);
void vec_dst (const vector signed char *, int, const int);
void vec_dst (const vector bool char *, int, const int);
void vec_dst (const vector unsigned short *, int, const int);
void vec_dst (const vector signed short *, int, const int);
void vec_dst (const vector bool short *, int, const int);
void vec_dst (const vector pixel *, int, const int);
void vec_dst (const vector unsigned int *, int, const int);
void vec_dst (const vector signed int *, int, const int);
void vec_dst (const vector bool int *, int, const int);
void vec_dst (const vector float *, int, const int);
void vec_dst (const unsigned char *, int, const int);
void vec_dst (const signed char *, int, const int);
void vec_dst (const unsigned short *, int, const int);
void vec_dst (const short *, int, const int);
void vec_dst (const unsigned int *, int, const int);
void vec_dst (const int *, int, const int);
void vec_dst (const float *, int, const int);

void vec_dstst (const vector unsigned char *, int, const int);
void vec_dstst (const vector signed char *, int, const int);
void vec_dstst (const vector bool char *, int, const int);
void vec_dstst (const vector unsigned short *, int, const int);
void vec_dstst (const vector signed short *, int, const int);
void vec_dstst (const vector bool short *, int, const int);
void vec_dstst (const vector pixel *, int, const int);
void vec_dstst (const vector unsigned int *, int, const int);
void vec_dstst (const vector signed int *, int, const int);
void vec_dstst (const vector bool int *, int, const int);
void vec_dstst (const vector float *, int, const int);
void vec_dstst (const unsigned char *, int, const int);
void vec_dstst (const signed char *, int, const int);
void vec_dstst (const unsigned short *, int, const int);
void vec_dstst (const short *, int, const int);
void vec_dstst (const unsigned int *, int, const int);
void vec_dstst (const int *, int, const int);
void vec_dstst (const unsigned long *, int, const int);
void vec_dstst (const long *, int, const int);
void vec_dstst (const float *, int, const int);

void vec_dststt (const vector unsigned char *, int, const int);
void vec_dststt (const vector signed char *, int, const int);
void vec_dststt (const vector bool char *, int, const int);
void vec_dststt (const vector unsigned short *, int, const int);
```

```
void vec_dststt (const vector signed short *, int, const int);
void vec_dststt (const vector bool short *, int, const int);
void vec_dststt (const vector pixel *, int, const int);
void vec_dststt (const vector unsigned int *, int, const int);
void vec_dststt (const vector signed int *, int, const int);
void vec_dststt (const vector bool int *, int, const int);
void vec_dststt (const vector float *, int, const int);
void vec_dststt (const unsigned char *, int, const int);
void vec_dststt (const signed char *, int, const int);
void vec_dststt (const unsigned short *, int, const int);
void vec_dststt (const short *, int, const int);
void vec_dststt (const unsigned int *, int, const int);
void vec_dststt (const int *, int, const int);
void vec_dststt (const float *, int, const int);

void vec_dstt (const vector unsigned char *, int, const int);
void vec_dstt (const vector signed char *, int, const int);
void vec_dstt (const vector bool char *, int, const int);
void vec_dstt (const vector unsigned short *, int, const int);
void vec_dstt (const vector signed short *, int, const int);
void vec_dstt (const vector bool short *, int, const int);
void vec_dstt (const vector pixel *, int, const int);
void vec_dstt (const vector unsigned int *, int, const int);
void vec_dstt (const vector signed int *, int, const int);
void vec_dstt (const vector bool int *, int, const int);
void vec_dstt (const vector float *, int, const int);
void vec_dstt (const unsigned char *, int, const int);
void vec_dstt (const signed char *, int, const int);
void vec_dstt (const unsigned short *, int, const int);
void vec_dstt (const short *, int, const int);
void vec_dstt (const unsigned int *, int, const int);
void vec_dstt (const int *, int, const int);
void vec_dstt (const float *, int, const int);

vector signed char vec_lvebx (int, char *);
vector unsigned char vec_lvebx (int, unsigned char *);

vector signed short vec_lvehx (int, short *);
vector unsigned short vec_lvehx (int, unsigned short *);

vector float vec_lvewx (int, float *);
vector signed int vec_lvewx (int, int *);
vector unsigned int vec_lvewx (int, unsigned int *);

vector unsigned char vec_lvsl (int, const unsigned char *);
vector unsigned char vec_lvsl (int, const signed char *);
vector unsigned char vec_lvsl (int, const unsigned short *);
vector unsigned char vec_lvsl (int, const short *);
vector unsigned char vec_lvsl (int, const unsigned int *);
vector unsigned char vec_lvsl (int, const int *);
vector unsigned char vec_lvsl (int, const float *);

vector unsigned char vec_lvsr (int, const unsigned char *);
vector unsigned char vec_lvsr (int, const signed char *);
vector unsigned char vec_lvsr (int, const unsigned short *);
vector unsigned char vec_lvsr (int, const short *);
vector unsigned char vec_lvsr (int, const unsigned int *);
vector unsigned char vec_lvsr (int, const int *);
```

```
vector unsigned char vec_lvsr (int, const float *);

void vec_stvebx (vector signed char, int, signed char *);
void vec_stvebx (vector unsigned char, int, unsigned char *);
void vec_stvebx (vector bool char, int, signed char *);
void vec_stvebx (vector bool char, int, unsigned char *);

void vec_stvehx (vector signed short, int, short *);
void vec_stvehx (vector unsigned short, int, unsigned short *);
void vec_stvehx (vector bool short, int, short *);
void vec_stvehx (vector bool short, int, unsigned short *);

void vec_stvewx (vector float, int, float *);
void vec_stvewx (vector signed int, int, int *);
void vec_stvewx (vector unsigned int, int, unsigned int *);
void vec_stvewx (vector bool int, int, int *);
void vec_stvewx (vector bool int, int, unsigned int *);

vector float vec_vaddfp (vector float, vector float);

vector signed char vec_vaddsbs (vector bool char, vector signed char);
vector signed char vec_vaddsbs (vector signed char, vector bool char);
vector signed char vec_vaddsbs (vector signed char, vector signed char);

vector signed short vec_vaddshs (vector bool short, vector signed short);
vector signed short vec_vaddshs (vector signed short, vector bool short);
vector signed short vec_vaddshs (vector signed short, vector signed short);

vector signed int vec_vaddsws (vector bool int, vector signed int);
vector signed int vec_vaddsws (vector signed int, vector bool int);
vector signed int vec_vaddsws (vector signed int, vector signed int);

vector signed char vec_vaddubm (vector bool char, vector signed char);
vector signed char vec_vaddubm (vector signed char, vector bool char);
vector signed char vec_vaddubm (vector signed char, vector signed char);
vector unsigned char vec_vaddubm (vector bool char, vector unsigned char);
vector unsigned char vec_vaddubm (vector unsigned char, vector bool char);
vector unsigned char vec_vaddubm (vector unsigned char, vector unsigned char);

vector unsigned char vec_vaddubs (vector bool char, vector unsigned char);
vector unsigned char vec_vaddubs (vector unsigned char, vector bool char);
vector unsigned char vec_vaddubs (vector unsigned char, vector unsigned char);

vector signed short vec_vadduhm (vector bool short, vector signed short);
vector signed short vec_vadduhm (vector signed short, vector bool short);
vector signed short vec_vadduhm (vector signed short, vector signed short);
vector unsigned short vec_vadduhm (vector bool short, vector unsigned short);
vector unsigned short vec_vadduhm (vector unsigned short, vector bool short);
vector unsigned short vec_vadduhm (vector unsigned short, vector unsigned short);

vector unsigned short vec_vadduhs (vector bool short, vector unsigned short);
vector unsigned short vec_vadduhs (vector unsigned short, vector bool short);
vector unsigned short vec_vadduhs (vector unsigned short, vector unsigned short);

vector signed int vec_vadduwm (vector bool int, vector signed int);
vector signed int vec_vadduwm (vector signed int, vector bool int);
vector signed int vec_vadduwm (vector signed int, vector signed int);
vector unsigned int vec_vadduwm (vector bool int, vector unsigned int);
```

```
vector unsigned int vec_vadduwm (vector unsigned int, vector bool int);
vector unsigned int vec_vadduwm (vector unsigned int, vector unsigned int);

vector unsigned int vec_vadduws (vector bool int, vector unsigned int);
vector unsigned int vec_vadduws (vector unsigned int, vector bool int);
vector unsigned int vec_vadduws (vector unsigned int, vector unsigned int);

vector signed char vec_vavgsb (vector signed char, vector signed char);

vector signed short vec_vavgsh (vector signed short, vector signed short);

vector signed int vec_vavgsw (vector signed int, vector signed int);

vector unsigned char vec_vavgub (vector unsigned char, vector unsigned char);

vector unsigned short vec_vavguh (vector unsigned short, vector unsigned short);

vector unsigned int vec_vavguw (vector unsigned int, vector unsigned int);

vector float vec_vcfsx (vector signed int, const int);

vector float vec_vcfux (vector unsigned int, const int);

vector bool int vec_vcmpeqfp (vector float, vector float);

vector bool char vec_vcmpequb (vector signed char, vector signed char);
vector bool char vec_vcmpequb (vector unsigned char, vector unsigned char);

vector bool short vec_vcmpequh (vector signed short, vector signed short);
vector bool short vec_vcmpequh (vector unsigned short, vector unsigned short);

vector bool int vec_vcmpequw (vector signed int, vector signed int);
vector bool int vec_vcmpequw (vector unsigned int, vector unsigned int);

vector bool int vec_vcmpgtfp (vector float, vector float);

vector bool char vec_vcmpgtsb (vector signed char, vector signed char);

vector bool short vec_vcmpgtsh (vector signed short, vector signed short);

vector bool int vec_vcmpgtsw (vector signed int, vector signed int);

vector bool char vec_vcmpgtub (vector unsigned char, vector unsigned char);

vector bool short vec_vcmpgtuh (vector unsigned short, vector unsigned short);

vector bool int vec_vcmpgtuw (vector unsigned int, vector unsigned int);

vector float vec_vmaxfp (vector float, vector float);

vector signed char vec_vmaxsb (vector bool char, vector signed char);
vector signed char vec_vmaxsb (vector signed char, vector bool char);
vector signed char vec_vmaxsb (vector signed char, vector signed char);

vector signed short vec_vmaxsh (vector bool short, vector signed short);
vector signed short vec_vmaxsh (vector signed short, vector bool short);
vector signed short vec_vmaxsh (vector signed short, vector signed short);
```

```
vector signed int vec_vmaxsw (vector bool int, vector signed int);
vector signed int vec_vmaxsw (vector signed int, vector bool int);
vector signed int vec_vmaxsw (vector signed int, vector signed int);

vector unsigned char vec_vmaxub (vector bool char, vector unsigned char);
vector unsigned char vec_vmaxub (vector unsigned char, vector bool char);
vector unsigned char vec_vmaxub (vector unsigned char, vector unsigned char);

vector unsigned short vec_vmaxuh (vector bool short, vector unsigned short);
vector unsigned short vec_vmaxuh (vector unsigned short, vector bool short);
vector unsigned short vec_vmaxuh (vector unsigned short, vector unsigned short);

vector unsigned int vec_vmaxuw (vector bool int, vector unsigned int);
vector unsigned int vec_vmaxuw (vector unsigned int, vector bool int);
vector unsigned int vec_vmaxuw (vector unsigned int, vector unsigned int);

vector float vec_vminfp (vector float, vector float);

vector signed char vec_vminsb (vector bool char, vector signed char);
vector signed char vec_vminsb (vector signed char, vector bool char);
vector signed char vec_vminsb (vector signed char, vector signed char);

vector signed short vec_vminsh (vector bool short, vector signed short);
vector signed short vec_vminsh (vector signed short, vector bool short);
vector signed short vec_vminsh (vector signed short, vector signed short);

vector signed int vec_vminsw (vector bool int, vector signed int);
vector signed int vec_vminsw (vector signed int, vector bool int);
vector signed int vec_vminsw (vector signed int, vector signed int);

vector unsigned char vec_vminub (vector bool char, vector unsigned char);
vector unsigned char vec_vminub (vector unsigned char, vector bool char);
vector unsigned char vec_vminub (vector unsigned char, vector unsigned char);

vector unsigned short vec_vminuh (vector bool short, vector unsigned short);
vector unsigned short vec_vminuh (vector unsigned short, vector bool short);
vector unsigned short vec_vminuh (vector unsigned short, vector unsigned short);

vector unsigned int vec_vminuw (vector bool int, vector unsigned int);
vector unsigned int vec_vminuw (vector unsigned int, vector bool int);
vector unsigned int vec_vminuw (vector unsigned int, vector unsigned int);

vector bool char vec_vmrghb (vector bool char, vector bool char);
vector signed char vec_vmrghb (vector signed char, vector signed char);
vector unsigned char vec_vmrghb (vector unsigned char, vector unsigned char);

vector bool short vec_vmrghh (vector bool short, vector bool short);
vector signed short vec_vmrghh (vector signed short, vector signed short);
vector unsigned short vec_vmrghh (vector unsigned short, vector unsigned short);
vector pixel vec_vmrghh (vector pixel, vector pixel);

vector float vec_vmrghw (vector float, vector float);
vector bool int vec_vmrghw (vector bool int, vector bool int);
vector signed int vec_vmrghw (vector signed int, vector signed int);
vector unsigned int vec_vmrghw (vector unsigned int, vector unsigned int);

vector bool char vec_vmrglb (vector bool char, vector bool char);
vector signed char vec_vmrglb (vector signed char, vector signed char);
```

```
vector unsigned char vec_vmrglb (vector unsigned char, vector unsigned char);

vector bool short vec_vmrglh (vector bool short, vector bool short);
vector signed short vec_vmrglh (vector signed short, vector signed short);
vector unsigned short vec_vmrglh (vector unsigned short, vector unsigned short);
vector pixel vec_vmrglh (vector pixel, vector pixel);

vector float vec_vmrglw (vector float, vector float);
vector signed int vec_vmrglw (vector signed int, vector signed int);
vector unsigned int vec_vmrglw (vector unsigned int, vector unsigned int);
vector bool int vec_vmrglw (vector bool int, vector bool int);

vector signed int vec_vmsummbm (vector signed char, vector unsigned char,
                                vector signed int);

vector signed int vec_vmsumshm (vector signed short, vector signed short,
                                vector signed int);

vector signed int vec_vmsumshs (vector signed short, vector signed short,
                                vector signed int);

vector unsigned int vec_vmsumubm (vector unsigned char, vector unsigned char,
                                  vector unsigned int);

vector unsigned int vec_vmsumuhm (vector unsigned short, vector unsigned short,
                                  vector unsigned int);

vector unsigned int vec_vmsumuhs (vector unsigned short, vector unsigned short,
                                  vector unsigned int);

vector signed short vec_vmulesb (vector signed char, vector signed char);

vector signed int vec_vmulesh (vector signed short, vector signed short);

vector unsigned short vec_vmuleub (vector unsigned char, vector unsigned char);

vector unsigned int vec_vmuleuh (vector unsigned short, vector unsigned short);

vector signed short vec_vmulosb (vector signed char, vector signed char);

vector signed int vec_vmulosh (vector signed short, vector signed short);

vector unsigned short vec_vmuloub (vector unsigned char, vector unsigned char);

vector unsigned int vec_vmulouh (vector unsigned short, vector unsigned short);

vector signed char vec_vpkshss (vector signed short, vector signed short);

vector unsigned char vec_vpkshus (vector signed short, vector signed short);

vector signed short vec_vpkswss (vector signed int, vector signed int);

vector unsigned short vec_vpkswus (vector signed int, vector signed int);

vector bool char vec_vpkuhum (vector bool short, vector bool short);
vector signed char vec_vpkuhum (vector signed short, vector signed short);
vector unsigned char vec_vpkuhum (vector unsigned short, vector unsigned short);
```

```
vector unsigned char vec_vpkuhus (vector unsigned short, vector unsigned short);

vector bool short vec_vpkuwum (vector bool int, vector bool int);
vector signed short vec_vpkuwum (vector signed int, vector signed int);
vector unsigned short vec_vpkuwum (vector unsigned int, vector unsigned int);

vector unsigned short vec_vpkuwus (vector unsigned int, vector unsigned int);

vector signed char vec_vrlb (vector signed char, vector unsigned char);
vector unsigned char vec_vrlb (vector unsigned char, vector unsigned char);

vector signed short vec_vrlh (vector signed short, vector unsigned short);
vector unsigned short vec_vrlh (vector unsigned short, vector unsigned short);

vector signed int vec_vrlw (vector signed int, vector unsigned int);
vector unsigned int vec_vrlw (vector unsigned int, vector unsigned int);

vector signed char vec_vslb (vector signed char, vector unsigned char);
vector unsigned char vec_vslb (vector unsigned char, vector unsigned char);

vector signed short vec_vslh (vector signed short, vector unsigned short);
vector unsigned short vec_vslh (vector unsigned short, vector unsigned short);

vector signed int vec_vslw (vector signed int, vector unsigned int);
vector unsigned int vec_vslw (vector unsigned int, vector unsigned int);

vector signed char vec_vspltb (vector signed char, const int);
vector unsigned char vec_vspltb (vector unsigned char, const int);
vector bool char vec_vspltb (vector bool char, const int);

vector bool short vec_vsplth (vector bool short, const int);
vector signed short vec_vsplth (vector signed short, const int);
vector unsigned short vec_vsplth (vector unsigned short, const int);
vector pixel vec_vsplth (vector pixel, const int);

vector float vec_vspltw (vector float, const int);
vector signed int vec_vspltw (vector signed int, const int);
vector unsigned int vec_vspltw (vector unsigned int, const int);
vector bool int vec_vspltw (vector bool int, const int);

vector signed char vec_vsrab (vector signed char, vector unsigned char);
vector unsigned char vec_vsrab (vector unsigned char, vector unsigned char);

vector signed short vec_vsrah (vector signed short, vector unsigned short);
vector unsigned short vec_vsrah (vector unsigned short, vector unsigned short);

vector signed int vec_vsraw (vector signed int, vector unsigned int);
vector unsigned int vec_vsraw (vector unsigned int, vector unsigned int);

vector signed char vec_vsrb (vector signed char, vector unsigned char);
vector unsigned char vec_vsrb (vector unsigned char, vector unsigned char);

vector signed short vec_vsrh (vector signed short, vector unsigned short);
vector unsigned short vec_vsrh (vector unsigned short, vector unsigned short);

vector signed int vec_vsrw (vector signed int, vector unsigned int);
vector unsigned int vec_vsrw (vector unsigned int, vector unsigned int);
```

```
vector float vec_vsubfp (vector float, vector float);

vector signed char vec_vsubsbs (vector bool char, vector signed char);
vector signed char vec_vsubsbs (vector signed char, vector bool char);
vector signed char vec_vsubsbs (vector signed char, vector signed char);

vector signed short vec_vsubshs (vector bool short, vector signed short);
vector signed short vec_vsubshs (vector signed short, vector bool short);
vector signed short vec_vsubshs (vector signed short, vector signed short);

vector signed int vec_vsubsws (vector bool int, vector signed int);
vector signed int vec_vsubsws (vector signed int, vector bool int);
vector signed int vec_vsubsws (vector signed int, vector signed int);

vector signed char vec_vsububm (vector bool char, vector signed char);
vector signed char vec_vsububm (vector signed char, vector bool char);
vector signed char vec_vsububm (vector signed char, vector signed char);
vector unsigned char vec_vsububm (vector bool char, vector unsigned char);
vector unsigned char vec_vsububm (vector unsigned char, vector bool char);
vector unsigned char vec_vsububm (vector unsigned char, vector unsigned char);

vector unsigned char vec_vsububs (vector bool char, vector unsigned char);
vector unsigned char vec_vsububs (vector unsigned char, vector bool char);
vector unsigned char vec_vsububs (vector unsigned char, vector unsigned char);

vector signed short vec_vsubuhm (vector bool short, vector signed short);
vector signed short vec_vsubuhm (vector signed short, vector bool short);
vector signed short vec_vsubuhm (vector signed short, vector signed short);
vector unsigned short vec_vsubuhm (vector bool short, vector unsigned short);
vector unsigned short vec_vsubuhm (vector unsigned short, vector bool short);
vector unsigned short vec_vsubuhm (vector unsigned short, vector unsigned short);

vector unsigned short vec_vsubuhs (vector bool short, vector unsigned short);
vector unsigned short vec_vsubuhs (vector unsigned short, vector bool short);
vector unsigned short vec_vsubuhs (vector unsigned short, vector unsigned short);

vector signed int vec_vsubuwm (vector bool int, vector signed int);
vector signed int vec_vsubuwm (vector signed int, vector bool int);
vector signed int vec_vsubuwm (vector signed int, vector signed int);
vector unsigned int vec_vsubuwm (vector bool int, vector unsigned int);
vector unsigned int vec_vsubuwm (vector unsigned int, vector bool int);
vector unsigned int vec_vsubuwm (vector unsigned int, vector unsigned int);

vector unsigned int vec_vsubuws (vector bool int, vector unsigned int);
vector unsigned int vec_vsubuws (vector unsigned int, vector bool int);
vector unsigned int vec_vsubuws (vector unsigned int, vector unsigned int);

vector signed int vec_vsum4sbs (vector signed char, vector signed int);

vector signed int vec_vsum4shs (vector signed short, vector signed int);

vector unsigned int vec_vsum4ubs (vector unsigned char, vector unsigned int);

vector unsigned int vec_vupkhpx (vector pixel);

vector bool short vec_vupkhsb (vector bool char);
vector signed short vec_vupkhsb (vector signed char);
```

```
vector bool int vec_vupkhsh (vector bool short);
vector signed int vec_vupkhsh (vector signed short);

vector unsigned int vec_vupklpx (vector pixel);

vector bool short vec_vupklsb (vector bool char);
vector signed short vec_vupklsb (vector signed char);

vector bool int vec_vupklsh (vector bool short);
vector signed int vec_vupklsh (vector signed short);
```

7.13.24.2 PowerPC AltiVec Built-in Functions Available on ISA 2.06

The AltiVec built-in functions described in this section are available on the PowerPC family of processors starting with ISA 2.06 or later. These are normally enabled by adding `-mvsx` to the command line.

When `-mvsx` is used, the following additional vector types are implemented.

```
vector unsigned __int128
vector signed __int128
vector unsigned long long int
vector signed long long int
vector double
```

The long long types are only implemented for 64-bit code generation.

Only functions excluded from the PVIPR are listed here.

```
void vec_dst (const unsigned long *, int, const int);
void vec_dst (const long *, int, const int);

void vec_dststt (const unsigned long *, int, const int);
void vec_dststt (const long *, int, const int);

void vec_dstt (const unsigned long *, int, const int);
void vec_dstt (const long *, int, const int);

vector unsigned char vec_lvsl (int, const unsigned long *);
vector unsigned char vec_lvsl (int, const long *);

vector unsigned char vec_lvsr (int, const unsigned long *);
vector unsigned char vec_lvsr (int, const long *);

vector unsigned char vec_lvsl (int, const double *);
vector unsigned char vec_lvsr (int, const double *);

vector double vec_vsx_ld (int, const vector double *);
vector double vec_vsx_ld (int, const double *);
vector float vec_vsx_ld (int, const vector float *);
vector float vec_vsx_ld (int, const float *);
vector bool int vec_vsx_ld (int, const vector bool int *);
vector signed int vec_vsx_ld (int, const vector signed int *);
vector signed int vec_vsx_ld (int, const int *);
vector signed int vec_vsx_ld (int, const long *);
vector unsigned int vec_vsx_ld (int, const vector unsigned int *);
vector unsigned int vec_vsx_ld (int, const unsigned int *);
vector unsigned int vec_vsx_ld (int, const unsigned long *);
vector bool short vec_vsx_ld (int, const vector bool short *);
vector pixel vec_vsx_ld (int, const vector pixel *);
```

```
vector signed short vec_vsx_ld (int, const vector signed short *);
vector signed short vec_vsx_ld (int, const short *);
vector unsigned short vec_vsx_ld (int, const vector unsigned short *);
vector unsigned short vec_vsx_ld (int, const unsigned short *);
vector bool char vec_vsx_ld (int, const vector bool char *);
vector signed char vec_vsx_ld (int, const vector signed char *);
vector signed char vec_vsx_ld (int, const signed char *);
vector unsigned char vec_vsx_ld (int, const vector unsigned char *);
vector unsigned char vec_vsx_ld (int, const unsigned char *);

void vec_vsx_st (vector double, int, vector double *);
void vec_vsx_st (vector double, int, double *);
void vec_vsx_st (vector float, int, vector float *);
void vec_vsx_st (vector float, int, float *);
void vec_vsx_st (vector signed int, int, vector signed int *);
void vec_vsx_st (vector signed int, int, int *);
void vec_vsx_st (vector unsigned int, int, vector unsigned int *);
void vec_vsx_st (vector unsigned int, int, unsigned int *);
void vec_vsx_st (vector bool int, int, vector bool int *);
void vec_vsx_st (vector bool int, int, unsigned int *);
void vec_vsx_st (vector bool int, int, int *);
void vec_vsx_st (vector signed short, int, vector signed short *);
void vec_vsx_st (vector signed short, int, short *);
void vec_vsx_st (vector unsigned short, int, vector unsigned short *);
void vec_vsx_st (vector unsigned short, int, unsigned short *);
void vec_vsx_st (vector bool short, int, vector bool short *);
void vec_vsx_st (vector bool short, int, unsigned short *);
void vec_vsx_st (vector pixel, int, vector pixel *);
void vec_vsx_st (vector pixel, int, unsigned short *);
void vec_vsx_st (vector pixel, int, short *);
void vec_vsx_st (vector bool short, int, short *);
void vec_vsx_st (vector signed char, int, vector signed char *);
void vec_vsx_st (vector signed char, int, signed char *);
void vec_vsx_st (vector unsigned char, int, vector unsigned char *);
void vec_vsx_st (vector unsigned char, int, unsigned char *);
void vec_vsx_st (vector bool char, int, vector bool char *);
void vec_vsx_st (vector bool char, int, unsigned char *);
void vec_vsx_st (vector bool char, int, signed char *);

vector double vec_xxpermdi (vector double, vector double, const int);
vector float vec_xxpermdi (vector float, vector float, const int);
vector __int128 vec_xxpermdi (vector __int128,
                              vector __int128, const int);
vector __uint128 vec_xxpermdi (vector __uint128,
                               vector __uint128, const int);
vector long long vec_xxpermdi (vector long long, vector long long, const int);
vector unsigned long long vec_xxpermdi (vector unsigned long long,
                                        vector unsigned long long, const int);
vector int vec_xxpermdi (vector int, vector int, const int);
vector unsigned int vec_xxpermdi (vector unsigned int,
                                  vector unsigned int, const int);
vector short vec_xxpermdi (vector short, vector short, const int);
vector unsigned short vec_xxpermdi (vector unsigned short,
                                    vector unsigned short, const int);
vector signed char vec_xxpermdi (vector signed char, vector signed char,
                                 const int);
vector unsigned char vec_xxpermdi (vector unsigned char,
                                   vector unsigned char, const int);
```

```
vector double vec_xxsldi (vector double, vector double, int);
vector float vec_xxsldi (vector float, vector float, int);
vector long long vec_xxsldi (vector long long, vector long long, int);
vector unsigned long long vec_xxsldi (vector unsigned long long,
                                      vector unsigned long long, int);
vector int vec_xxsldi (vector int, vector int, int);
vector unsigned int vec_xxsldi (vector unsigned int, vector unsigned int, int);
vector short vec_xxsldi (vector short, vector short, int);
vector unsigned short vec_xxsldi (vector unsigned short,
                                  vector unsigned short, int);
vector signed char vec_xxsldi (vector signed char, vector signed char, int);
vector unsigned char vec_xxsldi (vector unsigned char,
                                 vector unsigned char, int);
```

Note that the '`vec_ld`' and '`vec_st`' built-in functions always generate the AltiVec '`LVX`' and '`STVX`' instructions even if the VSX instruction set is available. The '`vec_vsx_ld`' and '`vec_vsx_st`' built-in functions always generate the VSX '`LXVD2X`', '`LXVW4X`', '`STXVD2X`', and '`STXVW4X`' instructions.

```
vector signed long long vec_signedo (vector float);
vector signed long long vec_signede (vector float);
vector unsigned long long vec_unsignedo (vector float);
vector unsigned long long vec_unsignede (vector float);
```

The overloaded built-ins `vec_signedo` and `vec_signede` are additional extensions to the built-ins as documented in the PVIPR.

7.13.24.3 PowerPC AltiVec Built-in Functions Available on ISA 2.07

If the ISA 2.07 additions to the vector/scalar (power8-vector) instruction set are available, the following additional functions are available for both 32-bit and 64-bit targets. For 64-bit targets, you can use *vector long* instead of *vector long long*, *vector bool long* instead of *vector bool long long*, and *vector unsigned long* instead of *vector unsigned long long*.

Only functions excluded from the PVIPR are listed here.

```
vector long long vec_vaddudm (vector long long, vector long long);
vector long long vec_vaddudm (vector bool long long, vector long long);
vector long long vec_vaddudm (vector long long, vector bool long long);
vector unsigned long long vec_vaddudm (vector unsigned long long,
                                       vector unsigned long long);
vector unsigned long long vec_vaddudm (vector bool unsigned long long,
                                       vector unsigned long long);
vector unsigned long long vec_vaddudm (vector unsigned long long,
                                       vector bool unsigned long long);

vector long long vec_vclz (vector long long);
vector unsigned long long vec_vclz (vector unsigned long long);
vector int vec_vclz (vector int);
vector unsigned int vec_vclz (vector int);
vector short vec_vclz (vector short);
vector unsigned short vec_vclz (vector unsigned short);
vector signed char vec_vclz (vector signed char);
vector unsigned char vec_vclz (vector unsigned char);

vector signed char vec_vclzb (vector signed char);
vector unsigned char vec_vclzb (vector unsigned char);
```

```
vector long long vec_vclzd (vector long long);
vector unsigned long long vec_vclzd (vector unsigned long long);

vector short vec_vclzh (vector short);
vector unsigned short vec_vclzh (vector unsigned short);

vector int vec_vclzw (vector int);
vector unsigned int vec_vclzw (vector int);

vector signed char vec_vgbbd (vector signed char);
vector unsigned char vec_vgbbd (vector unsigned char);

vector long long vec_vmaxsd (vector long long, vector long long);

vector unsigned long long vec_vmaxud (vector unsigned long long,
                                      unsigned vector long long);

vector long long vec_vminsd (vector long long, vector long long);

vector unsigned long long vec_vminud (vector long long, vector long long);

vector int vec_vpksdss (vector long long, vector long long);
vector unsigned int vec_vpksdss (vector long long, vector long long);

vector unsigned int vec_vpkudus (vector unsigned long long,
                                 vector unsigned long long);

vector int vec_vpkudum (vector long long, vector long long);
vector unsigned int vec_vpkudum (vector unsigned long long,
                                 vector unsigned long long);
vector bool int vec_vpkudum (vector bool long long, vector bool long long);

vector long long vec_vpopcnt (vector long long);
vector unsigned long long vec_vpopcnt (vector unsigned long long);
vector int vec_vpopcnt (vector int);
vector unsigned int vec_vpopcnt (vector int);
vector short vec_vpopcnt (vector short);
vector unsigned short vec_vpopcnt (vector unsigned short);
vector signed char vec_vpopcnt (vector signed char);
vector unsigned char vec_vpopcnt (vector unsigned char);

vector signed char vec_vpopcntb (vector signed char);
vector unsigned char vec_vpopcntb (vector unsigned char);

vector long long vec_vpopcntd (vector long long);
vector unsigned long long vec_vpopcntd (vector unsigned long long);

vector short vec_vpopcnth (vector short);
vector unsigned short vec_vpopcnth (vector unsigned short);

vector int vec_vpopcntw (vector int);
vector unsigned int vec_vpopcntw (vector int);

vector long long vec_vrld (vector long long, vector unsigned long long);
vector unsigned long long vec_vrld (vector unsigned long long,
                                    vector unsigned long long);

vector long long vec_vsld (vector long long, vector unsigned long long);
```

```
vector long long vec_vsld (vector unsigned long long,
                           vector unsigned long long);

vector long long vec_vsrad (vector long long, vector unsigned long long);
vector unsigned long long vec_vsrad (vector unsigned long long,
                                     vector unsigned long long);

vector long long vec_vsrd (vector long long, vector unsigned long long);
vector unsigned long long char vec_vsrd (vector unsigned long long,
                                         vector unsigned long long);

vector long long vec_vsubudm (vector long long, vector long long);
vector long long vec_vsubudm (vector bool long long, vector long long);
vector long long vec_vsubudm (vector long long, vector bool long long);
vector unsigned long long vec_vsubudm (vector unsigned long long,
                                       vector unsigned long long);
vector unsigned long long vec_vsubudm (vector bool long long,
                                       vector unsigned long long);
vector unsigned long long vec_vsubudm (vector unsigned long long,
                                       vector bool long long);

vector long long vec_vupkhsw (vector int);
vector unsigned long long vec_vupkhsw (vector unsigned int);

vector long long vec_vupklsw (vector int);
vector unsigned long long vec_vupklsw (vector int);
```

If the ISA 2.07 additions to the vector/scalar (power8-vector) instruction set are available, the following additional functions are available for 64-bit targets. New vector types (*vector __int128* and *vector __uint128*) are available to hold the *__int128* and *__uint128* types to use these builtins.

The normal vector extract, and set operations work on *vector __int128* and *vector __uint128* types, but the index value must be 0.

Only functions excluded from the PVIPR are listed here.

```
vector __int128 vec_vaddcuq (vector __int128, vector __int128);
vector __uint128 vec_vaddcuq (vector __uint128, vector __uint128);

vector __int128 vec_vadduqm (vector __int128, vector __int128);
vector __uint128 vec_vadduqm (vector __uint128, vector __uint128);

vector __int128 vec_vaddecuq (vector __int128, vector __int128,
                              vector __int128);
vector __uint128 vec_vaddecuq (vector __uint128, vector __uint128,
                               vector __uint128);

vector __int128 vec_vaddeuqm (vector __int128, vector __int128,
                              vector __int128);
vector __uint128 vec_vaddeuqm (vector __uint128, vector __uint128,
                               vector __uint128);

vector __int128 vec_vsubecuq (vector __int128, vector __int128,
                              vector __int128);
vector __uint128 vec_vsubecuq (vector __uint128, vector __uint128,
                               vector __uint128);

vector __int128 vec_vsubeuqm (vector __int128, vector __int128,
                              vector __int128);
```

```
vector __uint128 vec_vsubeuqm (vector __uint128, vector __uint128,
                               vector __uint128);

vector __int128 vec_vsubcuq (vector __int128, vector __int128);
vector __uint128 vec_vsubcuq (vector __uint128, vector __uint128);

__int128 vec_vsubuqm (__int128, __int128);
__uint128 vec_vsubuqm (__uint128, __uint128);

vector __int128 __builtin_bcdadd (vector __int128, vector __int128, const int);
vector unsigned char __builtin_bcdadd (vector unsigned char, vector unsigned char,
                                       const int);
int __builtin_bcdadd_lt (vector __int128, vector __int128, const int);
int __builtin_bcdadd_lt (vector unsigned char, vector unsigned char, const int);
int __builtin_bcdadd_eq (vector __int128, vector __int128, const int);
int __builtin_bcdadd_eq (vector unsigned char, vector unsigned char, const int);
int __builtin_bcdadd_gt (vector __int128, vector __int128, const int);
int __builtin_bcdadd_gt (vector unsigned char, vector unsigned char, const int);
int __builtin_bcdadd_ov (vector __int128, vector __int128, const int);
int __builtin_bcdadd_ov (vector unsigned char, vector unsigned char, const int);

vector __int128 __builtin_bcdsub (vector __int128, vector __int128, const int);
vector unsigned char __builtin_bcdsub (vector unsigned char, vector unsigned char,
                                       const int);
int __builtin_bcdsub_le (vector __int128, vector __int128, const int);
int __builtin_bcdsub_le (vector unsigned char, vector unsigned char, const int);
int __builtin_bcdsub_lt (vector __int128, vector __int128, const int);
int __builtin_bcdsub_lt (vector unsigned char, vector unsigned char, const int);
int __builtin_bcdsub_eq (vector __int128, vector __int128, const int);
int __builtin_bcdsub_eq (vector unsigned char, vector unsigned char, const int);
int __builtin_bcdsub_gt (vector __int128, vector __int128, const int);
int __builtin_bcdsub_gt (vector unsigned char, vector unsigned char, const int);
int __builtin_bcdsub_ge (vector __int128, vector __int128, const int);
int __builtin_bcdsub_ge (vector unsigned char, vector unsigned char, const int);
int __builtin_bcdsub_ov (vector __int128, vector __int128, const int);
int __builtin_bcdsub_ov (vector unsigned char, vector unsigned char, const int);
```

7.13.24.4 PowerPC AltiVec Built-in Functions Available on ISA 3.0

The following additional built-in functions are also available for the PowerPC family of processors, starting with ISA 3.0 (`-mcpu=power9`) or later.

Only instructions excluded from the PVIPR are listed here.

```
unsigned int scalar_extract_exp (double source);
unsigned long long int scalar_extract_exp (__ieee128 source);

unsigned long long int scalar_extract_sig (double source);
unsigned __int128 scalar_extract_sig (__ieee128 source);

double scalar_insert_exp (unsigned long long int significand,
                          unsigned long long int exponent);
double scalar_insert_exp (double significand, unsigned long long int exponent);

ieee_128 scalar_insert_exp (unsigned __int128 significand,
                            unsigned long long int exponent);
ieee_128 scalar_insert_exp (ieee_128 significand, unsigned long long int exponent);
vector ieee_128 scalar_insert_exp (vector unsigned __int128 significand,
```

```
                                    vector unsigned long long exponent);
vector unsigned long long scalar_extract_exp_to_vec (ieee_128);
vector unsigned __int128  scalar_extract_sig_to_vec (ieee_128);

int scalar_cmp_exp_gt (double arg1, double arg2);
int scalar_cmp_exp_lt (double arg1, double arg2);
int scalar_cmp_exp_eq (double arg1, double arg2);
int scalar_cmp_exp_unordered (double arg1, double arg2);

bool scalar_test_data_class (float source, const int condition);
bool scalar_test_data_class (double source, const int condition);
bool scalar_test_data_class (__ieee128 source, const int condition);

bool scalar_test_neg (float source);
bool scalar_test_neg (double source);
bool scalar_test_neg (__ieee128 source);
```

The `scalar_extract_exp` with a 64-bit source argument function requires an environment supporting ISA 3.0 or later. The `scalar_extract_exp` with a 128-bit source argument and `scalar_extract_sig` functions require a 64-bit environment supporting ISA 3.0 or later. The `scalar_extract_exp` and `scalar_extract_sig` built-in functions return the significand and the biased exponent value respectively of their `source` arguments. When supplied with a 64-bit `source` argument, the result returned by `scalar_extract_sig` has the `0x0010000000000000` bit set if the function's `source` argument is in normalized form. Otherwise, this bit is set to 0. When supplied with a 128-bit `source` argument, the `0x0001000000000000000000000000000` bit of the result is treated similarly. Note that the sign of the significand is not represented in the result returned from the `scalar_extract_sig` function. Use the `scalar_test_neg` function to test the sign of its `double` argument.

The `scalar_insert_exp` functions require a 64-bit environment supporting ISA 3.0 or later. When supplied with a 64-bit first argument, the `scalar_insert_exp` built-in function returns a double-precision floating point value that is constructed by assembling the values of its `significand` and `exponent` arguments. The sign of the result is copied from the most significant bit of the `significand` argument. The significand and exponent components of the result are composed of the least significant 11 bits of the `exponent` argument and the least significant 52 bits of the `significand` argument respectively.

When supplied with a 128-bit first argument, the `scalar_insert_exp` built-in function returns a quad-precision IEEE floating point value if the two arguments were scalar. If the two arguments are vectors, the return value is a vector IEEE floating point value. The sign bit of the result is copied from the most significant bit of the `significand` argument. The significand and exponent components of the result are composed of the least significant 15 bits of the `exponent` argument (element 0 on big-endian and element 1 on little-endian) and the least significant 112 bits of the `significand` argument respectively. Note, the `significand` is the scalar argument or in the case of vector arguments, `significand` is element 0 for big-endian and element 1 for little-endian.

The `scalar_extract_exp_to_vec`, and `scalar_extract_sig_to_vec` are similar to `scalar_extract_exp`, `scalar_extract_sig` except they return a vector result of type unsigned long long and unsigned __int128 respectively.

The `scalar_cmp_exp_gt`, `scalar_cmp_exp_lt`, `scalar_cmp_exp_eq`, and `scalar_cmp_exp_unordered` built-in functions return a non-zero value if `arg1` is greater than, less than, equal to, or not comparable to `arg2` respectively. The arguments are not comparable if one or the other equals NaN (not a number).

The `scalar_test_data_class` built-in function returns 1 if any of the condition tests enabled by the value of the `condition` variable are true, and 0 otherwise. The `condition` argument must be a compile-time constant integer with value not exceeding 127. The `condition` argument is encoded as a bitmask with each bit enabling the testing of a different condition, as characterized by the following:

```
0x40    Test for NaN
0x20    Test for +Infinity
0x10    Test for -Infinity
0x08    Test for +Zero
0x04    Test for -Zero
0x02    Test for +Denormal
0x01    Test for -Denormal
```

The `scalar_test_neg` built-in function returns 1 if its `source` argument holds a negative value, 0 otherwise.

The following built-in functions are also available for the PowerPC family of processors, starting with ISA 3.0 or later (`-mcpu=power9`). These string functions are described separately in order to group the descriptions closer to the function prototypes.

Only functions excluded from the PVIPR are listed here.

```
int vec_all_nez (vector signed char, vector signed char);
int vec_all_nez (vector unsigned char, vector unsigned char);
int vec_all_nez (vector signed short, vector signed short);
int vec_all_nez (vector unsigned short, vector unsigned short);
int vec_all_nez (vector signed int, vector signed int);
int vec_all_nez (vector unsigned int, vector unsigned int);

int vec_any_eqz (vector signed char, vector signed char);
int vec_any_eqz (vector unsigned char, vector unsigned char);
int vec_any_eqz (vector signed short, vector signed short);
int vec_any_eqz (vector unsigned short, vector unsigned short);
int vec_any_eqz (vector signed int, vector signed int);
int vec_any_eqz (vector unsigned int, vector unsigned int);

signed char vec_xlx (unsigned int index, vector signed char data);
unsigned char vec_xlx (unsigned int index, vector unsigned char data);
signed short vec_xlx (unsigned int index, vector signed short data);
unsigned short vec_xlx (unsigned int index, vector unsigned short data);
signed int vec_xlx (unsigned int index, vector signed int data);
unsigned int vec_xlx (unsigned int index, vector unsigned int data);
float vec_xlx (unsigned int index, vector float data);

signed char vec_xrx (unsigned int index, vector signed char data);
unsigned char vec_xrx (unsigned int index, vector unsigned char data);
signed short vec_xrx (unsigned int index, vector signed short data);
unsigned short vec_xrx (unsigned int index, vector unsigned short data);
signed int vec_xrx (unsigned int index, vector signed int data);
unsigned int vec_xrx (unsigned int index, vector unsigned int data);
float vec_xrx (unsigned int index, vector float data);
```

The `vec_all_nez`, `vec_any_eqz`, and `vec_cmpnez` perform pairwise comparisons between the elements at the same positions within their two vector arguments. The `vec_all_nez` function returns a non-zero value if and only if all pairwise comparisons are not equal and no element of either vector argument contains a zero. The `vec_any_eqz` function returns a non-zero value if and only if at least one pairwise comparison is equal or if at least one element of either vector argument contains a zero. The `vec_cmpnez` function returns a vector of the same type as its two arguments, within which each element consists of all ones to denote that either the corresponding elements of the incoming arguments are not equal or that at least one of the corresponding elements contains zero. Otherwise, the element of the returned vector contains all zeros.

The `vec_xlx` and `vec_xrx` functions extract the single element selected by the `index` argument from the vector represented by the `data` argument. The `index` argument always specifies a byte offset, regardless of the size of the vector element. With `vec_xlx`, `index` is the offset of the first byte of the element to be extracted. With `vec_xrx`, `index` represents the last byte of the element to be extracted, measured from the right end of the vector. In other words, the last byte of the element to be extracted is found at position `(15 - index)`. There is no requirement that `index` be a multiple of the vector element size. However, if the size of the vector element added to `index` is greater than 15, the content of the returned value is undefined.

The following functions are also available if the ISA 3.0 instruction set additions (`-mcpu=power9`) are available.

Only functions excluded from the PVIPR are listed here.

```
vector long long vec_vctz (vector long long);
vector unsigned long long vec_vctz (vector unsigned long long);
vector int vec_vctz (vector int);
vector unsigned int vec_vctz (vector int);
vector short vec_vctz (vector short);
vector unsigned short vec_vctz (vector unsigned short);
vector signed char vec_vctz (vector signed char);
vector unsigned char vec_vctz (vector unsigned char);

vector signed char vec_vctzb (vector signed char);
vector unsigned char vec_vctzb (vector unsigned char);

vector long long vec_vctzd (vector long long);
vector unsigned long long vec_vctzd (vector unsigned long long);

vector short vec_vctzh (vector short);
vector unsigned short vec_vctzh (vector unsigned short);

vector int vec_vctzw (vector int);
vector unsigned int vec_vctzw (vector int);

vector int vec_vprtyb (vector int);
vector unsigned int vec_vprtyb (vector unsigned int);
vector long long vec_vprtyb (vector long long);
vector unsigned long long vec_vprtyb (vector unsigned long long);

vector int vec_vprtybw (vector int);
vector unsigned int vec_vprtybw (vector unsigned int);

vector long long vec_vprtybd (vector long long);
vector unsigned long long vec_vprtybd (vector unsigned long long);
```

On 64-bit targets, if the ISA 3.0 additions (`-mcpu=power9`) are available:

```
vector long vec_vprtyb (vector long);
vector unsigned long vec_vprtyb (vector unsigned long);
```

```
vector __int128 vec_vprtyb (vector __int128);
vector __uint128 vec_vprtyb (vector __uint128);

vector long vec_vprtybd (vector long);
vector unsigned long vec_vprtybd (vector unsigned long);

vector __int128 vec_vprtybq (vector __int128);
vector __uint128 vec_vprtybd (vector __uint128);
```

The following built-in functions are available for the PowerPC family of processors, starting with ISA 3.0 or later (`-mcpu=power9`).

Only functions excluded from the PVIPR are listed here.

```
__vector unsigned char
vec_absdb (__vector unsigned char arg1, __vector unsigned char arg2);
__vector unsigned short
vec_absdh (__vector unsigned short arg1, __vector unsigned short arg2);
__vector unsigned int
vec_absdw (__vector unsigned int arg1, __vector unsigned int arg2);
```

The `vec_absd`, `vec_absdb`, `vec_absdh`, and `vec_absdw` built-in functions each computes the absolute differences of the pairs of vector elements supplied in its two vector arguments, placing the absolute differences into the corresponding elements of the vector result.

The following built-in functions are available for the PowerPC family of processors, starting with ISA 3.0 or later (`-mcpu=power9`):

```
vector unsigned int vec_vrlnm (vector unsigned int, vector unsigned int);
vector unsigned long long vec_vrlnm (vector unsigned long long,
                                     vector unsigned long long);
```

The result of `vec_vrlnm` is obtained by rotating each element of the first argument vector left and ANDing it with a mask. The second argument vector contains the mask beginning in bits 11:15, the mask end in bits 19:23, and the shift count in bits 27:31, of each element.

If the cryptographic instructions are enabled (`-mcrypto` or `-mcpu=power8`), the following builtins are enabled.

Only functions excluded from the PVIPR are listed here.

```
vector unsigned long long __builtin_crypto_vsbox (vector unsigned long long);

vector unsigned long long __builtin_crypto_vcipher (vector unsigned long long,
                                                    vector unsigned long long);

vector unsigned long long __builtin_crypto_vcipherlast
                                     (vector unsigned long long,
                                      vector unsigned long long);

vector unsigned long long __builtin_crypto_vncipher (vector unsigned long long,
                                                     vector unsigned long long);

vector unsigned long long __builtin_crypto_vncipherlast (vector unsigned long long,
                                                         vector unsigned long long);

vector unsigned char __builtin_crypto_vpermxor (vector unsigned char,
                                                vector unsigned char,
                                                vector unsigned char);

vector unsigned short __builtin_crypto_vpermxor (vector unsigned short,
                                                 vector unsigned short,
```

```
                                             vector unsigned short);

vector unsigned int __builtin_crypto_vpermxor (vector unsigned int,
                                               vector unsigned int,
                                               vector unsigned int);

vector unsigned long long __builtin_crypto_vpermxor (vector unsigned long long,
                                                     vector unsigned long long,
                                                     vector unsigned long long);

vector unsigned char __builtin_crypto_vpmsumb (vector unsigned char,
                                               vector unsigned char);

vector unsigned short __builtin_crypto_vpmsumh (vector unsigned short,
                                                vector unsigned short);

vector unsigned int __builtin_crypto_vpmsumw (vector unsigned int,
                                              vector unsigned int);

vector unsigned long long __builtin_crypto_vpmsumd (vector unsigned long long,
                                                    vector unsigned long long);

vector unsigned long long __builtin_crypto_vshasigmad (vector unsigned long long,
                                                       int, int);

vector unsigned int __builtin_crypto_vshasigmaw (vector unsigned int, int, int);
```

The second argument to *__builtin_crypto_vshasigmad* and *__builtin_crypto_vshasigmaw* must be a constant integer that is 0 or 1. The third argument to these built-in functions must be a constant integer in the range of 0 to 15.

The following sign extension builtins are provided:

```
vector signed int vec_signexti (vector signed char a);
vector signed long long vec_signextll (vector signed char a);
vector signed int vec_signexti (vector signed short a);
vector signed long long vec_signextll (vector signed short a);
vector signed long long vec_signextll (vector signed int a);
vector signed long long vec_signextq (vector signed long long a);
```

Each element of the result is produced by sign-extending the element of the input vector that would fall in the least significant portion of the result element. For example, a sign-extension of a vector signed char to a vector signed long long will sign extend the rightmost byte of each doubleword.

7.13.24.5 PowerPC AltiVec Built-in Functions Available on ISA 3.1

The following additional built-in functions are also available for the PowerPC family of processors, starting with ISA 3.1 (`-mcpu=power10`):

int vec_test_lsbb_all_ones (vector signed char);
int vec_test_lsbb_all_ones (vector unsigned char);
int vec_test_lsbb_all_ones (vector bool char);

The builtin `vec_test_lsbb_all_ones` returns 1 if the least significant bit in each byte is equal to 1. It returns 0 otherwise.

int vec_test_lsbb_all_zeros (vector signed char);
int vec_test_lsbb_all_zeros (vector unsigned char);
int vec_test_lsbb_all_zeros (vector bool char);

The builtin `vec_test_lsbb_all_zeros` returns 1 if the least significant bit in each byte is equal to zero. It returns 0 otherwise.

```
vector unsigned long long int
vec_cfuge (vector unsigned long long int, vector unsigned long long int);
```

Perform a vector centrifuge operation, as if implemented by the `vcfuged` instruction.

```
vector unsigned long long int
vec_cntlzm (vector unsigned long long int, vector unsigned long long int);
```

Perform a vector count leading zeros under bit mask operation, as if implemented by the `vclzdm` instruction.

```
vector unsigned long long int
vec_cnttzm (vector unsigned long long int, vector unsigned long long int);
```

Perform a vector count trailing zeros under bit mask operation, as if implemented by the `vctzdm` instruction.

```
vector signed char
vec_clrl (vector signed char a, unsigned int n);
vector unsigned char
vec_clrl (vector unsigned char a, unsigned int n);
```

Clear the left-most `(16 - n)` bytes of vector argument `a`, as if implemented by the `vclrlb` instruction on a big-endian target and by the `vclrrb` instruction on a little-endian target. A value of `n` that is greater than 16 is treated as if it equaled 16.

```
vector signed char
vec_clrr (vector signed char a, unsigned int n);
vector unsigned char
vec_clrr (vector unsigned char a, unsigned int n);
```

Clear the right-most `(16 - n)` bytes of vector argument `a`, as if implemented by the `vclrrb` instruction on a big-endian target and by the `vclrlb` instruction on a little-endian target. A value of `n` that is greater than 16 is treated as if it equaled 16.

```
vector unsigned long long int
vec_gnb (vector unsigned __int128, const unsigned char);
```

Perform a 128-bit vector gather operation, as if implemented by the `vgnb` instruction. The second argument must be a literal integer value between 2 and 7 inclusive.

Vector Extract

```
vector unsigned long long int
vec_extractl (vector unsigned char, vector unsigned char, unsigned int);
vector unsigned long long int
vec_extractl (vector unsigned short, vector unsigned short, unsigned int);
vector unsigned long long int
vec_extractl (vector unsigned int, vector unsigned int, unsigned int);
vector unsigned long long int
vec_extractl (vector unsigned long long, vector unsigned long long, unsigned int);
```

Extract an element from two concatenated vectors starting at the given byte index in natural-endian order, and place it zero-extended in doubleword 1 of the result according to natural element order. If the byte index is out of range for the data type, the intrinsic will be rejected. For little-endian, this output will match the placement by the hardware instruction, i.e., dword[0] in RTL notation. For big-endian, an additional instruction is needed to move it from the `"left"` doubleword to the `"right"` one. For little-endian, semantics matching the `vextdubvrx`, `vextduhvrx`, `vextduwvrx` instruction will be generated, while for big-endian, semantics matching the `vextdubvlx`, `vextduhvlx`, `vextduwvlx` instructions will be generated. Note that some fairly anomalous results can be generated if the byte index is not aligned on an element boundary for the element being extracted. This is a limitation of the bi-endian vector programming model is consistent with the limitation on `vec_perm`.

```
vector unsigned long long int
vec_extracth (vector unsigned char, vector unsigned char, unsigned int);
vector unsigned long long int
vec_extracth (vector unsigned short, vector unsigned short,
      unsigned int);
vector unsigned long long int
vec_extracth (vector unsigned int, vector unsigned int, unsigned int);
vector unsigned long long int
vec_extracth (vector unsigned long long, vector unsigned long long,
      unsigned int);
```

Extract an element from two concatenated vectors starting at the given byte index. The index is based on big endian order for a little endian system. Similarly, the index is based on little endian order for a big endian system. The extraced elements are zero-extended and put in doubleword 1 according to natural element order. If the byte index is out of range for the data type, the intrinsic will be rejected. For little-endian, this output will match the placement by the hardware instruction (vextdubvrx, vextduhvrx, vextduwvrx, vextddvrx) i.e., dword[0] in RTL notation. For big-endian, an additional instruction is needed to move it from the "left" doubleword to the "right" one. For little-endian, semantics matching the `vextdubvlx`, `vextduhvlx`, `vextduwvlx` instructions will be generated, while for big-endian, semantics matching the `vextdubvrx`, `vextduhvrx`, `vextduwvrx` instructions will be generated. Note that some fairly anomalous results can be generated if the byte index is not aligned on the element boundary for the element being extracted. This is a limitation of the bi-endian vector programming model consistent with the limitation on `vec_perm`.

```
vector unsigned long long int
vec_pdep (vector unsigned long long int, vector unsigned long long int);
```

Perform a vector parallel bits deposit operation, as if implemented by the `vpdepd` instruction.

Vector Insert

```
vector unsigned char
vec_insertl (unsigned char, vector unsigned char, unsigned int);
vector unsigned short
vec_insertl (unsigned short, vector unsigned short, unsigned int);
vector unsigned int
vec_insertl (unsigned int, vector unsigned int, unsigned int);
vector unsigned long long
vec_insertl (unsigned long long, vector unsigned long long,
      unsigned int);
vector unsigned char
vec_insertl (vector unsigned char, vector unsigned char, unsigned int;
vector unsigned short
vec_insertl (vector unsigned short, vector unsigned short,
      unsigned int);
vector unsigned int
vec_insertl (vector unsigned int, vector unsigned int, unsigned int);
```

Let src be the first argument, when the first argument is a scalar, or the rightmost element of the left doubleword of the first argument, when the first argument is a vector. Insert the source into the destination at the position given by the third argument, using natural element order in the second argument. The rest of the second argument is unchanged. If the byte index is greater than 14 for halfwords, greater than 12 for words, or greater than 8 for doublewords the result is undefined. For little-endian, the generated code will be semantically equivalent to `vins[bhwd]rx` instructions. Similarly for big-endian it will be semantically equivalent to `vins[bhwd]lx`. Note that some fairly anomalous results can be generated if the byte index is not aligned on an element boundary for the type of element being inserted.

```
vector unsigned char
vec_inserth (unsigned char, vector unsigned char, unsigned int);
vector unsigned short
vec_inserth (unsigned short, vector unsigned short, unsigned int);
vector unsigned int
vec_inserth (unsigned int, vector unsigned int, unsigned int);
vector unsigned long long
vec_inserth (unsigned long long, vector unsigned long long,
        unsigned int);
vector unsigned char
vec_inserth (vector unsigned char, vector unsigned char, unsigned int);
vector unsigned short
vec_inserth (vector unsigned short, vector unsigned short,
        unsigned int);
vector unsigned int
vec_inserth (vector unsigned int, vector unsigned int, unsigned int);
```

Let src be the first argument, when the first argument is a scalar, or the rightmost element of the first argument, when the first argument is a vector. Insert src into the second argument at the position identified by the third argument, using opposite element order in the second argument, and leaving the rest of the second argument unchanged. If the byte index is greater than 14 for halfwords, 12 for words, or 8 for doublewords, the intrinsic will be rejected. Note that the underlying hardware instruction uses the same register for the second argument and the result. For little-endian, the code generation will be semantically equivalent to `vins[bhwd]lx`, while for big-endian it will be semantically equivalent to `vins[bhwd]rx`. Note that some fairly anomalous results can be generated if the byte index is not aligned on an element boundary for the sort of element being inserted.

Vector Replace Element

```
vector signed int vec_replace_elt (vector signed int, signed int,
        const int);
vector unsigned int vec_replace_elt (vector unsigned int,
        unsigned int, const int);
vector float vec_replace_elt (vector float, float, const int);
vector signed long long vec_replace_elt (vector signed long long,
        signed long long, const int);
vector unsigned long long vec_replace_elt (vector unsigned long long,
        unsigned long long, const int);
vector double rec_replace_elt (vector double, double, const int);
```

The third argument (constrained to [0,3]) identifies the natural-endian element number of the first argument that will be replaced by the second argument to produce the result. The other elements of the first argument will remain unchanged in the result.

If it's desirable to insert a word at an unaligned position, use vec_replace_unaligned instead.

Vector Replace Unaligned

vector unsigned char vec_replace_unaligned (vector unsigned char,
    signed int, const int);
vector unsigned char vec_replace_unaligned (vector unsigned char,
    unsigned int, const int);
vector unsigned char vec_replace_unaligned (vector unsigned char,
    float, const int);
vector unsigned char vec_replace_unaligned (vector unsigned char,
    signed long long, const int);
vector unsigned char vec_replace_unaligned (vector unsigned char,
    unsigned long long, const int);
vector unsigned char vec_replace_unaligned (vector unsigned char,
    double, const int);

The second argument replaces a portion of the first argument to produce the result, with the rest of the first argument unchanged in the result. The third argument identifies the byte index (using left-to-right, or big-endian order) where the high-order byte of the second argument will be placed, with the remaining bytes of the second argument placed naturally "to the right" of the high-order byte.

The programmer is responsible for understanding the endianness issues involved with the first argument and the result.

Vector Shift Left Double Bit Immediate

vector signed char vec_sldb (vector signed char, vector signed char,
    const unsigned int);
vector unsigned char vec_sldb (vector unsigned char,
    vector unsigned char, const unsigned int);
vector signed short vec_sldb (vector signed short, vector signed short,
    const unsigned int);
vector unsigned short vec_sldb (vector unsigned short,
    vector unsigned short, const unsigned int);
vector signed int vec_sldb (vector signed int, vector signed int,
    const unsigned int);
vector unsigned int vec_sldb (vector unsigned int, vector unsigned int,
    const unsigned int);
vector signed long long vec_sldb (vector signed long long,
    vector signed long long, const unsigned int);
vector unsigned long long vec_sldb (vector unsigned long long,
    vector unsigned long long, const unsigned int);
vector signed __int128 vec_sldb (vector signed __int128,
    vector signed __int128, const unsigned int);
vector unsigned __int128 vec_sldb (vector unsigned __int128,
    vector unsigned __int128, const unsigned int);

Shift the combined input vectors left by the amount specified by the low-order three bits of the third argument, and return the leftmost remaining 128 bits. Code using this instruction must be endian-aware.

Vector Shift Right Double Bit Immediate

vector signed char vec_srdb (vector signed char, vector signed char,
    const unsigned int);
vector unsigned char vec_srdb (vector unsigned char, vector unsigned char,
    const unsigned int);
vector signed short vec_srdb (vector signed short, vector signed short,
    const unsigned int);
vector unsigned short vec_srdb (vector unsigned short, vector unsigned short,
    const unsigned int);
vector signed int vec_srdb (vector signed int, vector signed int,
    const unsigned int);

```
vector unsigned int vec_srdb (vector unsigned int, vector unsigned int,
      const unsigned int);
vector signed long long vec_srdb (vector signed long long,
      vector signed long long, const unsigned int);
vector unsigned long long vec_srdb (vector unsigned long long,
      vector unsigned long long, const unsigned int);
vector signed __int128 vec_srdb (vector signed __int128,
      vector signed __int128, const unsigned int);
vector unsigned __int128 vec_srdb (vector unsigned __int128,
      vector unsigned __int128, const unsigned int);
```

Shift the combined input vectors right by the amount specified by the low-order three bits of the third argument, and return the remaining 128 bits. Code using this built-in must be endian-aware.

Vector Splat

```
vector signed int vec_splati (const signed int);
vector float vec_splati (const float);
```

Splat a 32-bit immediate into a vector of words.

```
vector double vec_splatid (const float);
```

Convert a single precision floating-point value to double-precision and splat the result to a vector of double-precision floats.

```
vector signed int vec_splati_ins (vector signed int,
      const unsigned int, const signed int);
vector unsigned int vec_splati_ins (vector unsigned int,
      const unsigned int, const unsigned int);
vector float vec_splati_ins (vector float, const unsigned int,
      const float);
```

Argument 2 must be either 0 or 1. Splat the value of argument 3 into the word identified by argument 2 of each doubleword of argument 1 and return the result. The other words of argument 1 are unchanged.

Vector Blend Variable

```
vector signed char vec_blendv (vector signed char, vector signed char,
      vector unsigned char);
vector unsigned char vec_blendv (vector unsigned char,
      vector unsigned char, vector unsigned char);
vector signed short vec_blendv (vector signed short,
      vector signed short, vector unsigned short);
vector unsigned short vec_blendv (vector unsigned short,
      vector unsigned short, vector unsigned short);
vector signed int vec_blendv (vector signed int, vector signed int,
      vector unsigned int);
vector unsigned int vec_blendv (vector unsigned int,
      vector unsigned int, vector unsigned int);
vector signed long long vec_blendv (vector signed long long,
      vector signed long long, vector unsigned long long);
vector unsigned long long vec_blendv (vector unsigned long long,
      vector unsigned long long, vector unsigned long long);
vector float vec_blendv (vector float, vector float,
      vector unsigned int);
vector double vec_blendv (vector double, vector double,
      vector unsigned long long);
```

Blend the first and second argument vectors according to the sign bits of the corresponding elements of the third argument vector. This is similar to the `vsel` and `xxsel` instructions but for bigger elements.

Vector Permute Extended

vector signed char vec_permx (vector signed char, vector signed char,
`vector unsigned char, const int);`
vector unsigned char vec_permx (vector unsigned char,
`vector unsigned char, vector unsigned char, const int);`
vector signed short vec_permx (vector signed short,
`vector signed short, vector unsigned char, const int);`
vector unsigned short vec_permx (vector unsigned short,
`vector unsigned short, vector unsigned char, const int);`
vector signed int vec_permx (vector signed int, vector signed int,
`vector unsigned char, const int);`
vector unsigned int vec_permx (vector unsigned int,
`vector unsigned int, vector unsigned char, const int);`
vector signed long long vec_permx (vector signed long long,
`vector signed long long, vector unsigned char, const int);`
vector unsigned long long vec_permx (vector unsigned long long,
`vector unsigned long long, vector unsigned char, const int);`
vector float (vector float, vector float, vector unsigned char,
`const int);`
vector double (vector double, vector double, vector unsigned char,
`const int);`

Perform a partial permute of the first two arguments, which form a 32-byte section of an emulated vector up to 256 bytes wide, using the partial permute control vector in the third argument. The fourth argument (constrained to values of 0-7) identifies which 32-byte section of the emulated vector is contained in the first two arguments.

vector unsigned long long int
vec_pext (vector unsigned long long int, vector unsigned long long int);

Perform a vector parallel bit extract operation, as if implemented by the `vpextd` instruction.

vector unsigned char vec_stril (vector unsigned char);
vector signed char vec_stril (vector signed char);
vector unsigned short vec_stril (vector unsigned short);
vector signed short vec_stril (vector signed short);

Isolate the left-most non-zero elements of the incoming vector argument, replacing all elements to the right of the left-most zero element found within the argument with zero. The typical implementation uses the `vstribl` or `vstrihl` instruction on big-endian targets and uses the `vstribr` or `vstrihr` instruction on little-endian targets.

int vec_stril_p (vector unsigned char);
int vec_stril_p (vector signed char);
int short vec_stril_p (vector unsigned short);
int vec_stril_p (vector signed short);

Return a non-zero value if and only if the argument contains a zero element. The typical implementation uses the `vstribl.` or `vstrihl.` instruction on big-endian targets and uses the `vstribr.` or `vstrihr.` instruction on little-endian targets. Choose this built-in to check for presence of zero element if the same argument is also passed to `vec_stril`.

vector unsigned char vec_strir (vector unsigned char);
vector signed char vec_strir (vector signed char);
vector unsigned short vec_strir (vector unsigned short);
vector signed short vec_strir (vector signed short);

Isolate the right-most non-zero elements of the incoming vector argument, replacing all elements to the left of the right-most zero element found within the argument with zero.

The typical implementation uses the `vstribr` or `vstrihr` instruction on big-endian targets and uses the `vstribl` or `vstrihl` instruction on little-endian targets.

```
int vec_strir_p (vector unsigned char);
int vec_strir_p (vector signed char);
int short vec_strir_p (vector unsigned short);
int vec_strir_p (vector signed short);
```

Return a non-zero value if and only if the argument contains a zero element. The typical implementation uses the `vstribr.` or `vstrihr.` instruction on big-endian targets and uses the `vstribl.` or `vstrihl.` instruction on little-endian targets. Choose this built-in to check for presence of zero element if the same argument is also passed to `vec_strir`.

```
vector unsigned char
vec_ternarylogic (vector unsigned char, vector unsigned char,
                  vector unsigned char, const unsigned int);
vector unsigned short
vec_ternarylogic (vector unsigned short, vector unsigned short,
                  vector unsigned short, const unsigned int);
vector unsigned int
vec_ternarylogic (vector unsigned int, vector unsigned int,
                  vector unsigned int, const unsigned int);
vector unsigned long long int
vec_ternarylogic (vector unsigned long long int, vector unsigned long long int,
                  vector unsigned long long int, const unsigned int);
vector unsigned __int128
vec_ternarylogic (vector unsigned __int128, vector unsigned __int128,
                  vector unsigned __int128, const unsigned int);
```

Perform a 128-bit vector evaluate operation, as if implemented by the `xxeval` instruction. The fourth argument must be a literal integer value between 0 and 255 inclusive.

```
vector unsigned char vec_genpcvm (vector unsigned char, const int);
vector unsigned short vec_genpcvm (vector unsigned short, const int);
vector unsigned int vec_genpcvm (vector unsigned int, const int);
vector unsigned int vec_genpcvm (vector unsigned long long int,
                                 const int);
```

Vector Integer Multiply/Divide/Modulo

```
vector signed int
vec_mulh (vector signed int a, vector signed int b);
vector unsigned int
vec_mulh (vector unsigned int a, vector unsigned int b);
```

For each integer value `i` from 0 to 3, do the following. The integer value in word element `i` of a is multiplied by the integer value in word element `i` of b. The high-order 32 bits of the 64-bit product are placed into word element `i` of the vector returned.

```
vector signed long long
vec_mulh (vector signed long long a, vector signed long long b);
vector unsigned long long
vec_mulh (vector unsigned long long a, vector unsigned long long b);
```

For each integer value `i` from 0 to 1, do the following. The integer value in doubleword element `i` of a is multiplied by the integer value in doubleword element `i` of b. The high-order 64 bits of the 128-bit product are placed into doubleword element `i` of the vector returned.

```
vector unsigned long long
vec_mul (vector unsigned long long a, vector unsigned long long b);
vector signed long long
vec_mul (vector signed long long a, vector signed long long b);
```

For each integer value `i` from 0 to 1, do the following. The integer value in doubleword element `i` of a is multiplied by the integer value in doubleword element `i` of b. The low-order 64 bits of the 128-bit product are placed into doubleword element `i` of the vector returned.

vector signed int
vec_div (vector signed int *a*, vector signed int *b*);
vector unsigned int
vec_div (vector unsigned int *a*, vector unsigned int *b*);

For each integer value `i` from 0 to 3, do the following. The integer in word element `i` of a is divided by the integer in word element `i` of b. The unique integer quotient is placed into the word element `i` of the vector returned. If an attempt is made to perform any of the divisions <anything> ÷ 0 then the quotient is undefined.

vector signed long long
vec_div (vector signed long long *a*, vector signed long long *b*);
vector unsigned long long
vec_div (vector unsigned long long *a*, vector unsigned long long *b*);

For each integer value `i` from 0 to 1, do the following. The integer in doubleword element `i` of a is divided by the integer in doubleword element `i` of b. The unique integer quotient is placed into the doubleword element `i` of the vector returned. If an attempt is made to perform any of the divisions 0x8000_0000_0000_0000 ÷ -1 or <anything> ÷ 0 then the quotient is undefined.

vector signed int
vec_dive (vector signed int *a*, vector signed int *b*);
vector unsigned int
vec_dive (vector unsigned int *a*, vector unsigned int *b*);

For each integer value `i` from 0 to 3, do the following. The integer in word element `i` of a is shifted left by 32 bits, then divided by the integer in word element `i` of b. The unique integer quotient is placed into the word element `i` of the vector returned. If the quotient cannot be represented in 32 bits, or if an attempt is made to perform any of the divisions <anything> ÷ 0 then the quotient is undefined.

vector signed long long
vec_dive (vector signed long long *a*, vector signed long long *b*);
vector unsigned long long
vec_dive (vector unsigned long long *a*, vector unsigned long long *b*);

For each integer value `i` from 0 to 1, do the following. The integer in doubleword element `i` of a is shifted left by 64 bits, then divided by the integer in doubleword element `i` of b. The unique integer quotient is placed into the doubleword element `i` of the vector returned. If the quotient cannot be represented in 64 bits, or if an attempt is made to perform <anything> ÷ 0 then the quotient is undefined.

vector signed int
vec_mod (vector signed int *a*, vector signed int *b*);
vector unsigned int
vec_mod (vector unsigned int *a*, vector unsigned int *b*);

For each integer value `i` from 0 to 3, do the following. The integer in word element `i` of a is divided by the integer in word element `i` of b. The unique integer remainder is placed into the word element `i` of the vector returned. If an attempt is made to perform any of the divisions 0x8000_0000 ÷ -1 or <anything> ÷ 0 then the remainder is undefined.

vector signed long long
vec_mod (vector signed long long *a*, vector signed long long *b*);
vector unsigned long long

vec_mod (vector unsigned long long *a*, vector unsigned long long *b*);

For each integer value `i` from 0 to 1, do the following. The integer in doubleword element `i` of a is divided by the integer in doubleword element `i` of b. The unique integer remainder is placed into the doubleword element `i` of the vector returned. If an attempt is made to perform `<anything>` ÷ 0 then the remainder is undefined.

Generate PCV from specified Mask size, as if implemented by the `xxgenpcvbm`, `xxgenpcvhm`, `xxgenpcvwm` instructions, where immediate value is either 0, 1, 2 or 3.

```
vector unsigned __int128 vec_rl (vector unsigned __int128 A,
                                 vector unsigned __int128 B);
vector signed __int128 vec_rl (vector signed __int128 A,
                               vector unsigned __int128 B);
```

Result value: Each element of R is obtained by rotating the corresponding element of A left by the number of bits specified by the corresponding element of B.

```
vector unsigned __int128 vec_rlmi (vector unsigned __int128,
                                   vector unsigned __int128,
                                   vector unsigned __int128);
vector signed __int128 vec_rlmi (vector signed __int128,
                                 vector signed __int128,
                                 vector unsigned __int128);
```

Returns the result of rotating the first input and inserting it under mask into the second input. The first bit in the mask, the last bit in the mask are obtained from the two 7-bit fields bits [108:115] and bits [117:123] respectively of the second input. The shift is obtained from the third input in the 7-bit field [125:131] where all bits counted from zero at the left.

```
vector unsigned __int128 vec_rlnm (vector unsigned __int128,
                                   vector unsigned __int128,
                                   vector unsigned __int128);
vector signed __int128 vec_rlnm (vector signed __int128,
                                 vector unsigned __int128,
                                 vector unsigned __int128);
```

Returns the result of rotating the first input and ANDing it with a mask. The first bit in the mask and the last bit in the mask are obtained from the two 7-bit fields bits [117:123] and bits [125:131] respectively of the second input. The shift is obtained from the third input in the 7-bit field bits [125:131] where all bits counted from zero at the left.

```
vector unsigned __int128 vec_sl(vector unsigned __int128 A, vector unsigned __int128 B);
vector signed __int128 vec_sl(vector signed __int128 A, vector unsigned __int128 B);
```

Result value: Each element of R is obtained by shifting the corresponding element of A left by the number of bits specified by the corresponding element of B.

```
vector unsigned __int128 vec_sr(vector unsigned __int128 A, vector unsigned __int128 B);
vector signed __int128 vec_sr(vector signed __int128 A, vector unsigned __int128 B);
```

Result value: Each element of R is obtained by shifting the corresponding element of A right by the number of bits specified by the corresponding element of B.

```
vector unsigned __int128 vec_sra(vector unsigned __int128 A, vector unsigned __int128 B);
vector signed __int128 vec_sra(vector signed __int128 A, vector unsigned __int128 B);
```

Result value: Each element of R is obtained by arithmetic shifting the corresponding element of A right by the number of bits specified by the corresponding element of B.

```
vector unsigned __int128 vec_mule (vector unsigned long long,
                                   vector unsigned long long);
vector signed __int128 vec_mule (vector signed long long,
                                 vector signed long long);
```

Returns a vector containing a 128-bit integer result of multiplying the even doubleword elements of the two inputs.

vector unsigned __int128 vec_mulo (vector unsigned long long,
 vector unsigned long long);
vector signed __int128 vec_mulo (vector signed long long,
 vector signed long long);

Returns a vector containing a 128-bit integer result of multiplying the odd doubleword elements of the two inputs.

vector unsigned __int128 vec_div (vector unsigned __int128,
 vector unsigned __int128);
vector signed __int128 vec_div (vector signed __int128,
 vector signed __int128);

Returns the result of dividing the first operand by the second operand. An attempt to divide any value by zero or to divide the most negative signed 128-bit integer by negative one results in an undefined value.

vector unsigned __int128 vec_dive (vector unsigned __int128,
 vector unsigned __int128);
vector signed __int128 vec_dive (vector signed __int128,
 vector signed __int128);

The result is produced by shifting the first input left by 128 bits and dividing by the second. If an attempt is made to divide by zero or the result is larger than 128 bits, the result is undefined.

vector unsigned __int128 vec_mod (vector unsigned __int128,
 vector unsigned __int128);
vector signed __int128 vec_mod (vector signed __int128,
 vector signed __int128);

The result is the modulo result of dividing the first input by the second input.

The following builtins perform 128-bit vector comparisons. The `vec_all_xx`, `vec_any_xx`, and `vec_cmpxx`, where `xx` is one of the operations `eq, ne, gt, lt, ge, le` perform pairwise comparisons between the elements at the same positions within their two vector arguments. The `vec_all_xx`function returns a non-zero value if and only if all pairwise comparisons are true. The `vec_any_xx` function returns a non-zero value if and only if at least one pairwise comparison is true. The `vec_cmpxx`function returns a vector of the same type as its two arguments, within which each element consists of all ones to denote that specified logical comparison of the corresponding elements was true. Otherwise, the element of the returned vector contains all zeros.

```
vector bool __int128 vec_cmpeq (vector signed __int128, vector signed __int128);
vector bool __int128 vec_cmpeq (vector unsigned __int128, vector unsigned __int128);
vector bool __int128 vec_cmpne (vector signed __int128, vector signed __int128);
vector bool __int128 vec_cmpne (vector unsigned __int128, vector unsigned __int128);
vector bool __int128 vec_cmpgt (vector signed __int128, vector signed __int128);
vector bool __int128 vec_cmpgt (vector unsigned __int128, vector unsigned __int128);
vector bool __int128 vec_cmplt (vector signed __int128, vector signed __int128);
vector bool __int128 vec_cmplt (vector unsigned __int128, vector unsigned __int128);
vector bool __int128 vec_cmpge (vector signed __int128, vector signed __int128);
vector bool __int128 vec_cmpge (vector unsigned __int128, vector unsigned __int128);
vector bool __int128 vec_cmple (vector signed __int128, vector signed __int128);
vector bool __int128 vec_cmple (vector unsigned __int128, vector unsigned __int128);

int vec_all_eq (vector signed __int128, vector signed __int128);
int vec_all_eq (vector unsigned __int128, vector unsigned __int128);
```

```
int vec_all_ne (vector signed __int128, vector signed __int128);
int vec_all_ne (vector unsigned __int128, vector unsigned __int128);
int vec_all_gt (vector signed __int128, vector signed __int128);
int vec_all_gt (vector unsigned __int128, vector unsigned __int128);
int vec_all_lt (vector signed __int128, vector signed __int128);
int vec_all_lt (vector unsigned __int128, vector unsigned __int128);
int vec_all_ge (vector signed __int128, vector signed __int128);
int vec_all_ge (vector unsigned __int128, vector unsigned __int128);
int vec_all_le (vector signed __int128, vector signed __int128);
int vec_all_le (vector unsigned __int128, vector unsigned __int128);

int vec_any_eq (vector signed __int128, vector signed __int128);
int vec_any_eq (vector unsigned __int128, vector unsigned __int128);
int vec_any_ne (vector signed __int128, vector signed __int128);
int vec_any_ne (vector unsigned __int128, vector unsigned __int128);
int vec_any_gt (vector signed __int128, vector signed __int128);
int vec_any_gt (vector unsigned __int128, vector unsigned __int128);
int vec_any_lt (vector signed __int128, vector signed __int128);
int vec_any_lt (vector unsigned __int128, vector unsigned __int128);
int vec_any_ge (vector signed __int128, vector signed __int128);
int vec_any_ge (vector unsigned __int128, vector unsigned __int128);
int vec_any_le (vector signed __int128, vector signed __int128);
int vec_any_le (vector unsigned __int128, vector unsigned __int128);
```

The following instances are extension of the existing overloaded built-ins `vec_sld`, `vec_sldw`, `vec_slo`, `vec_sro`, `vec_srl` that are documented in the PVIPR.

vector signed __int128 vec_sld (vector signed __int128,
```
      vector signed __int128, const unsigned int);
```
vector unsigned __int128 vec_sld (vector unsigned __int128,
```
      vector unsigned __int128, const unsigned int);
```
vector signed __int128 vec_sldw (vector signed __int128,
```
      vector signed __int128, const unsigned int);
```
vector unsigned __int128 vec_sldw (vector unsigned __int,
```
      vector unsigned __int128, const unsigned int);
```
vector signed __int128 vec_slo (vector signed __int128,
```
      vector signed char);
```
vector signed __int128 vec_slo (vector signed __int128,
```
      vector unsigned char);
```
vector unsigned __int128 vec_slo (vector unsigned __int128,
```
      vector signed char);
```
vector unsigned __int128 vec_slo (vector unsigned __int128,
```
      vector unsigned char);
```
vector signed __int128 vec_sro (vector signed __int128,
```
      vector signed char);
```
vector signed __int128 vec_sro (vector signed __int128,
```
      vector unsigned char);
```
vector unsigned __int128 vec_sro (vector unsigned __int128,
```
      vector signed char);
```
vector unsigned __int128 vec_sro (vector unsigned __int128,
```
      vector unsigned char);
```
vector signed __int128 vec_srl (vector signed __int128,
```
      vector unsigned char);
```
vector unsigned __int128 vec_srl (vector unsigned __int128,
```
      vector unsigned char);
```

7.13.25 PowerPC Hardware Transactional Memory Built-in Functions

GCC provides two interfaces for accessing the Hardware Transactional Memory (HTM) instructions available on some of the PowerPC family of processors (eg, POWER8). The two interfaces come in a low level interface, consisting of built-in functions specific to PowerPC and a higher level interface consisting of inline functions that are common between PowerPC and S/390.

7.13.25.1 PowerPC HTM Low Level Built-in Functions

The following low level built-in functions are available with `-mhtm` or `-mcpu=CPU` where CPU is 'power8' or later. They all generate the machine instruction that is part of the name.

The HTM builtins (with the exception of `__builtin_tbegin`) return the full 4-bit condition register value set by their associated hardware instruction. The header file `htmintrin.h` defines some macros that can be used to decipher the return value. The `__builtin_tbegin` builtin returns a simple `true` or `false` value depending on whether a transaction was successfully started or not. The arguments of the builtins match exactly the type and order of the associated hardware instruction's operands, except for the `__builtin_tcheck` builtin, which does not take any input arguments. Refer to the ISA manual for a description of each instruction's operands.

```
unsigned int __builtin_tbegin (unsigned int);
unsigned int __builtin_tend (unsigned int);

unsigned int __builtin_tabort (unsigned int);
unsigned int __builtin_tabortdc (unsigned int, unsigned int, unsigned int);
unsigned int __builtin_tabortdci (unsigned int, unsigned int, int);
unsigned int __builtin_tabortwc (unsigned int, unsigned int, unsigned int);
unsigned int __builtin_tabortwci (unsigned int, unsigned int, int);

unsigned int __builtin_tcheck (void);
unsigned int __builtin_treclaim (unsigned int);
unsigned int __builtin_trechkpt (void);
unsigned int __builtin_tsr (unsigned int);
```

In addition to the above HTM built-ins, we have added built-ins for some common extended mnemonics of the HTM instructions:

```
unsigned int __builtin_tendall (void);
unsigned int __builtin_tresume (void);
unsigned int __builtin_tsuspend (void);
```

Note that the semantics of the above HTM builtins are required to mimic the locking semantics used for critical sections. Builtins that are used to create a new transaction or restart a suspended transaction must have lock acquisition like semantics while those builtins that end or suspend a transaction must have lock release like semantics. Specifically, this must mimic lock semantics as specified by C++11, for example: Lock acquisition is as-if an execution of __atomic_exchange_n(&globallock,1,__ATOMIC_ACQUIRE) that returns 0, and lock release is as-if an execution of __atomic_store(&globallock,0,__ATOMIC_RELEASE), with globallock being an implicit implementation-defined lock used for all transactions. The HTM instructions associated with with the builtins inherently provide the correct acquisition and release hardware barriers required. However, the compiler must also be prohibited from moving loads and stores across the builtins in a way that would violate their semantics. This has been accomplished by adding memory barriers to the associated

HTM instructions (which is a conservative approach to provide acquire and release semantics). Earlier versions of the compiler did not treat the HTM instructions as memory barriers. A `__TM_FENCE__` macro has been added, which can be used to determine whether the current compiler treats HTM instructions as memory barriers or not. This allows the user to explicitly add memory barriers to their code when using an older version of the compiler.

The following set of built-in functions are available to gain access to the HTM specific special purpose registers.

```
unsigned long __builtin_get_texasr (void);
unsigned long __builtin_get_texasru (void);
unsigned long __builtin_get_tfhar (void);
unsigned long __builtin_get_tfiar (void);

void __builtin_set_texasr (unsigned long);
void __builtin_set_texasru (unsigned long);
void __builtin_set_tfhar (unsigned long);
void __builtin_set_tfiar (unsigned long);
```

Example usage of these low level built-in functions may look like:

```
#include <htmintrin.h>

int num_retries = 10;

while (1)
  {
    if (__builtin_tbegin (0))
      {
        /* Transaction State Initiated.  */
        if (is_locked (lock))
          __builtin_tabort (0);
        ... transaction code...
        __builtin_tend (0);
        break;
      }
    else
      {
        /* Transaction State Failed.  Use locks if the transaction
           failure is "persistent" or we've tried too many times.  */
        if (num_retries-- <= 0
            || _TEXASRU_FAILURE_PERSISTENT (__builtin_get_texasru ()))
          {
            acquire_lock (lock);
            ... non transactional fallback path...
            release_lock (lock);
            break;
          }
      }
  }
```

One final built-in function has been added that returns the value of the 2-bit Transaction State field of the Machine Status Register (MSR) as stored in `CR0`.

```
unsigned long __builtin_ttest (void)
```

This built-in can be used to determine the current transaction state using the following code example:

```
#include <htmintrin.h>
```

```
unsigned char tx_state = _HTM_STATE (__builtin_ttest ());

if (tx_state == _HTM_TRANSACTIONAL)
  {
    /* Code to use in transactional state.  */
  }
else if (tx_state == _HTM_NONTRANSACTIONAL)
  {
    /* Code to use in non-transactional state.  */
  }
else if (tx_state == _HTM_SUSPENDED)
  {
    /* Code to use in transaction suspended state.  */
  }
```

7.13.25.2 PowerPC HTM High Level Inline Functions

The following high level HTM interface is made available by including `<htmxlintrin.h>` and using `-mhtm` or `-mcpu=CPU` where CPU is 'power8' or later. This interface is common between PowerPC and S/390, allowing users to write one HTM source implementation that can be compiled and executed on either system.

```
long __TM_simple_begin (void);
long __TM_begin (void* const TM_buff);
long __TM_end (void);
void __TM_abort (void);
void __TM_named_abort (unsigned char const code);
void __TM_resume (void);
void __TM_suspend (void);

long __TM_is_user_abort (void* const TM_buff);
long __TM_is_named_user_abort (void* const TM_buff, unsigned char *code);
long __TM_is_illegal (void* const TM_buff);
long __TM_is_footprint_exceeded (void* const TM_buff);
long __TM_nesting_depth (void* const TM_buff);
long __TM_is_nested_too_deep(void* const TM_buff);
long __TM_is_conflict(void* const TM_buff);
long __TM_is_failure_persistent(void* const TM_buff);
long __TM_failure_address(void* const TM_buff);
long long __TM_failure_code(void* const TM_buff);
```

Using these common set of HTM inline functions, we can create a more portable version of the HTM example in the previous section that will work on either PowerPC or S/390:

```
#include <htmxlintrin.h>

int num_retries = 10;
TM_buff_type TM_buff;

while (1)
  {
    if (__TM_begin (TM_buff) == _HTM_TBEGIN_STARTED)
      {
        /* Transaction State Initiated.  */
        if (is_locked (lock))
          __TM_abort ();
        ... transaction code...
        __TM_end ();
        break;
```

```
        }
      else
        {
          /* Transaction State Failed.  Use locks if the transaction
             failure is "persistent" or we've tried too many times.  */
          if (num_retries-- <= 0
              || __TM_is_failure_persistent (TM_buff))
            {
              acquire_lock (lock);
              ... non transactional fallback path...
              release_lock (lock);
              break;
            }
        }
    }
```

7.13.26 PowerPC Atomic Memory Operation Functions

ISA 3.0 of the PowerPC added new atomic memory operation (amo) instructions. GCC provides support for these instructions in 64-bit environments. All of the functions are declared in the include file `amo.h`.

The functions supported are:

```
#include <amo.h>

uint32_t amo_lwat_add (uint32_t *, uint32_t);
uint32_t amo_lwat_xor (uint32_t *, uint32_t);
uint32_t amo_lwat_ior (uint32_t *, uint32_t);
uint32_t amo_lwat_and (uint32_t *, uint32_t);
uint32_t amo_lwat_umax (uint32_t *, uint32_t);
uint32_t amo_lwat_umin (uint32_t *, uint32_t);
uint32_t amo_lwat_swap (uint32_t *, uint32_t);

int32_t amo_lwat_sadd (int32_t *, int32_t);
int32_t amo_lwat_smax (int32_t *, int32_t);
int32_t amo_lwat_smin (int32_t *, int32_t);
int32_t amo_lwat_sswap (int32_t *, int32_t);

uint64_t amo_ldat_add (uint64_t *, uint64_t);
uint64_t amo_ldat_xor (uint64_t *, uint64_t);
uint64_t amo_ldat_ior (uint64_t *, uint64_t);
uint64_t amo_ldat_and (uint64_t *, uint64_t);
uint64_t amo_ldat_umax (uint64_t *, uint64_t);
uint64_t amo_ldat_umin (uint64_t *, uint64_t);
uint64_t amo_ldat_swap (uint64_t *, uint64_t);

int64_t amo_ldat_sadd (int64_t *, int64_t);
int64_t amo_ldat_smax (int64_t *, int64_t);
int64_t amo_ldat_smin (int64_t *, int64_t);
int64_t amo_ldat_sswap (int64_t *, int64_t);

void amo_stwat_add (uint32_t *, uint32_t);
void amo_stwat_xor (uint32_t *, uint32_t);
void amo_stwat_ior (uint32_t *, uint32_t);
void amo_stwat_and (uint32_t *, uint32_t);
void amo_stwat_umax (uint32_t *, uint32_t);
void amo_stwat_umin (uint32_t *, uint32_t);
```

```
void amo_stwat_sadd (int32_t *, int32_t);
void amo_stwat_smax (int32_t *, int32_t);
void amo_stwat_smin (int32_t *, int32_t);

void amo_stdat_add (uint64_t *, uint64_t);
void amo_stdat_xor (uint64_t *, uint64_t);
void amo_stdat_ior (uint64_t *, uint64_t);
void amo_stdat_and (uint64_t *, uint64_t);
void amo_stdat_umax (uint64_t *, uint64_t);
void amo_stdat_umin (uint64_t *, uint64_t);

void amo_stdat_sadd (int64_t *, int64_t);
void amo_stdat_smax (int64_t *, int64_t);
void amo_stdat_smin (int64_t *, int64_t);
```

7.13.27 PowerPC Matrix-Multiply Assist Built-in Functions

ISA 3.1 of the PowerPC added new Matrix-Multiply Assist (MMA) instructions. GCC provides support for these instructions through the following built-in functions which are enabled with the `-mmma` option. The vec_t type below is defined to be a normal vector unsigned char type. The uint2, uint4 and uint8 parameters are 2-bit, 4-bit and 8-bit unsigned integer constants respectively. The compiler will verify that they are constants and that their values are within range.

The built-in functions supported are:

```
void __builtin_mma_xvi4ger8 (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvi8ger4 (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvi16ger2 (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvi16ger2s (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvf16ger2 (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvbf16ger2 (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvf32ger (__vector_quad *, vec_t, vec_t);

void __builtin_mma_xvi4ger8pp (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvi8ger4pp (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvi8ger4spp(__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvi16ger2pp (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvi16ger2spp (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvf16ger2pp (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvf16ger2pn (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvf16ger2np (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvf16ger2nn (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvbf16ger2pp (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvbf16ger2pn (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvbf16ger2np (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvbf16ger2nn (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvf32gerpp (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvf32gerpn (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvf32gernp (__vector_quad *, vec_t, vec_t);
void __builtin_mma_xvf32gernn (__vector_quad *, vec_t, vec_t);

void __builtin_mma_pmxvi4ger8 (__vector_quad *, vec_t, vec_t, uint4, uint4, uint8);
void __builtin_mma_pmxvi4ger8pp (__vector_quad *, vec_t, vec_t, uint4, uint4, uint8);

void __builtin_mma_pmxvi8ger4 (__vector_quad *, vec_t, vec_t, uint4, uint4, uint4);
void __builtin_mma_pmxvi8ger4pp (__vector_quad *, vec_t, vec_t, uint4, uint4, uint4);
void __builtin_mma_pmxvi8ger4spp(__vector_quad *, vec_t, vec_t, uint4, uint4, uint4);
```

```
void __builtin_mma_pmxvi16ger2 (__vector_quad *, vec_t, vec_t, uint4, uint4, uint2);
void __builtin_mma_pmxvi16ger2s (__vector_quad *, vec_t, vec_t, uint4, uint4, uint2);
void __builtin_mma_pmxvf16ger2 (__vector_quad *, vec_t, vec_t, uint4, uint4, uint2);
void __builtin_mma_pmxvbf16ger2 (__vector_quad *, vec_t, vec_t, uint4, uint4, uint2);

void __builtin_mma_pmxvi16ger2pp (__vector_quad *, vec_t, vec_t, uint4, uint4, uint2);
void __builtin_mma_pmxvi16ger2spp (__vector_quad *, vec_t, vec_t, uint4, uint4, uint2);
void __builtin_mma_pmxvf16ger2pp (__vector_quad *, vec_t, vec_t, uint4, uint4, uint2);
void __builtin_mma_pmxvf16ger2pn (__vector_quad *, vec_t, vec_t, uint4, uint4, uint2);
void __builtin_mma_pmxvf16ger2np (__vector_quad *, vec_t, vec_t, uint4, uint4, uint2);
void __builtin_mma_pmxvf16ger2nn (__vector_quad *, vec_t, vec_t, uint4, uint4, uint2);
void __builtin_mma_pmxvbf16ger2pp (__vector_quad *, vec_t, vec_t, uint4, uint4, uint2);
void __builtin_mma_pmxvbf16ger2pn (__vector_quad *, vec_t, vec_t, uint4, uint4, uint2);
void __builtin_mma_pmxvbf16ger2np (__vector_quad *, vec_t, vec_t, uint4, uint4, uint2);
void __builtin_mma_pmxvbf16ger2nn (__vector_quad *, vec_t, vec_t, uint4, uint4, uint2);

void __builtin_mma_pmxvf32ger (__vector_quad *, vec_t, vec_t, uint4, uint4);
void __builtin_mma_pmxvf32gerpp (__vector_quad *, vec_t, vec_t, uint4, uint4);
void __builtin_mma_pmxvf32gerpn (__vector_quad *, vec_t, vec_t, uint4, uint4);
void __builtin_mma_pmxvf32gernp (__vector_quad *, vec_t, vec_t, uint4, uint4);
void __builtin_mma_pmxvf32gernn (__vector_quad *, vec_t, vec_t, uint4, uint4);

void __builtin_mma_xvf64ger (__vector_quad *, __vector_pair, vec_t);
void __builtin_mma_xvf64gerpp (__vector_quad *, __vector_pair, vec_t);
void __builtin_mma_xvf64gerpn (__vector_quad *, __vector_pair, vec_t);
void __builtin_mma_xvf64gernp (__vector_quad *, __vector_pair, vec_t);
void __builtin_mma_xvf64gernn (__vector_quad *, __vector_pair, vec_t);

void __builtin_mma_pmxvf64ger (__vector_quad *, __vector_pair, vec_t, uint4, uint2);
void __builtin_mma_pmxvf64gerpp (__vector_quad *, __vector_pair, vec_t, uint4, uint2);
void __builtin_mma_pmxvf64gerpn (__vector_quad *, __vector_pair, vec_t, uint4, uint2);
void __builtin_mma_pmxvf64gernp (__vector_quad *, __vector_pair, vec_t, uint4, uint2);
void __builtin_mma_pmxvf64gernn (__vector_quad *, __vector_pair, vec_t, uint4, uint2);

void __builtin_mma_xxmtacc (__vector_quad *);
void __builtin_mma_xxmfacc (__vector_quad *);
void __builtin_mma_xxsetaccz (__vector_quad *);

void __builtin_mma_build_acc (__vector_quad *, vec_t, vec_t, vec_t, vec_t);
void __builtin_mma_disassemble_acc (void *, __vector_quad *);

void __builtin_vsx_build_pair (__vector_pair *, vec_t, vec_t);
void __builtin_vsx_disassemble_pair (void *, __vector_pair *);

vec_t __builtin_vsx_xvcvspbf16 (vec_t);
vec_t __builtin_vsx_xvcvbf16spn (vec_t);

__vector_pair __builtin_vsx_lxvp (size_t, __vector_pair *);
void __builtin_vsx_stxvp (__vector_pair, size_t, __vector_pair *);
```

7.13.28 PRU Built-in Functions

GCC provides a couple of special builtin functions to aid in utilizing special PRU instructions.

The built-in functions supported are:

`void __delay_cycles (constant long long cycles)` [Built-in Function]

This inserts an instruction sequence that takes exactly *cycles* cycles (between 0 and 0xffffffff) to complete. The inserted sequence may use jumps, loops, or no-ops, and does not interfere with any other instructions. Note that *cycles* must be a compile-time constant integer - that is, you must pass a number, not a variable that may be optimized to a constant later. The number of cycles delayed by this builtin is exact.

`void __halt (void)` [Built-in Function]

This inserts a HALT instruction to stop processor execution.

`unsigned int __lmbd (unsigned int wordval, unsigned int bitval)` [Built-in Function]

This inserts LMBD instruction to calculate the left-most bit with value *bitval* in value *wordval*. Only the least significant bit of *bitval* is taken into account.

7.13.29 RISC-V Built-in Functions

These built-in functions are available for the RISC-V family of processors.

`void * __builtin_thread_pointer (void)` [Built-in Function]

Returns the value that is currently set in the '`tp`' register.

`void __builtin_riscv_pause (void)` [Built-in Function]

Generates the `pause` (hint) machine instruction. If the target implements the Zihintpause extension, it indicates that the current hart should be temporarily paused or slowed down.

7.13.30 RISC-V Vector Intrinsics

GCC supports vector intrinsics as specified in version 0.11 of the RISC-V vector intrinsic specification, which is available at the following link: `https://github.com/riscv-non-isa/rvv-intrinsic-doc/tree/v0.11.x`. All of these functions are declared in the include file `riscv_vector.h`.

7.13.31 CORE-V Built-in Functions

For more information on all CORE-V built-ins, please see `https://github.com/openhwgroup/core-v-sw/blob/master/specifications/corev-builtin-spec.md`

These built-in functions are available for the CORE-V MAC machine architecture. For more information on CORE-V built-ins, please see `https://github.com/openhwgroup/core-v-sw/blob/master/specifications/corev-builtin-spec.md#listing-of-multiply-accumulate-builtins-xcvmac`.

`int32_t __builtin_riscv_cv_mac_mac (int32_t, int32_t, int32_t)` [Built-in Function]

Generated assembler `cv.mac`

`int32_t __builtin_riscv_cv_mac_msu (int32_t, int32_t, int32_t)` [Built-in Function]

Generates the `cv.msu` machine instruction.

`uint32_t __builtin_riscv_cv_mac_muluN (uint32_t, uint32_t, uint8_t)` [Built-in Function]
Generates the `cv.muluN` machine instruction.

`uint32_t __builtin_riscv_cv_mac_mulhhuN (uint32_t, uint32_t, uint8_t)` [Built-in Function]
Generates the `cv.mulhhuN` machine instruction.

`int32_t __builtin_riscv_cv_mac_mulsN (int32_t, int32_t, uint8_t)` [Built-in Function]
Generates the `cv.mulsN` machine instruction.

`int32_t __builtin_riscv_cv_mac_mulhhsN (int32_t, int32_t, uint8_t)` [Built-in Function]
Generates the `cv.mulhhsN` machine instruction.

`uint32_t __builtin_riscv_cv_mac_muluRN (uint32_t, uint32_t, uint8_t)` [Built-in Function]
Generates the `cv.muluRN` machine instruction.

`uint32_t __builtin_riscv_cv_mac_mulhhuRN (uint32_t, uint32_t, uint8_t)` [Built-in Function]
Generates the `cv.mulhhuRN` machine instruction.

`int32_t __builtin_riscv_cv_mac_mulsRN (int32_t, int32_t, uint8_t)` [Built-in Function]
Generates the `cv.mulsRN` machine instruction.

`int32_t __builtin_riscv_cv_mac_mulhhsRN (int32_t, int32_t, uint8_t)` [Built-in Function]
Generates the `cv.mulhhsRN` machine instruction.

`uint32_t __builtin_riscv_cv_mac_macuN (uint32_t, uint32_t, uint8_t)` [Built-in Function]
Generates the `cv.macuN` machine instruction.

`uint32_t __builtin_riscv_cv_mac_machhuN (uint32_t, uint32_t, uint8_t)` [Built-in Function]
Generates the `cv.machhuN` machine instruction.

`int32_t __builtin_riscv_cv_mac_macsN (int32_t, int32_t, uint8_t)` [Built-in Function]
Generates the `cv.macsN` machine instruction.

`int32_t __builtin_riscv_cv_mac_machhsN (int32_t, int32_t, uint8_t)` [Built-in Function]
Generates the `cv.machhsN` machine instruction.

`uint32_t __builtin_riscv_cv_mac_macuRN (uint32_t, uint32_t, uint8_t)` [Built-in Function]
Generates the `cv.macuRN` machine instruction.

`uint32_t __builtin_riscv_cv_mac_machhuRN (uint32_t, uint32_t, uint8_t)` [Built-in Function]
Generates the `cv.machhuRN` machine instruction.

`int32_t __builtin_riscv_cv_mac_macsRN (int32_t, int32_t, uint8_t)` [Built-in Function]
Generates the `cv.macsRN` machine instruction.

`int32_t __builtin_riscv_cv_mac_machhsRN (int32_t, int32_t, uint8_t)` [Built-in Function]
Generates the `cv.machhsRN` machine instruction.

These built-in functions are available for the CORE-V ALU machine architecture. For more information on CORE-V built-ins, please see `https://github.com/openhwgroup/core-v-sw/blob/master/specifications/corev-builtin-spec.md#listing-of-miscellaneous-alu-builtins-xcvalu`

`int __builtin_riscv_cv_alu_slet (int32_t, int32_t)` [Built-in Function]
Generated assembler `cv.slet`

`int __builtin_riscv_cv_alu_sletu (uint32_t, uint32_t)` [Built-in Function]
Generated assembler `cv.sletu`

`int32_t __builtin_riscv_cv_alu_min (int32_t, int32_t)` [Built-in Function]
Generated assembler `cv.min`

`uint32_t __builtin_riscv_cv_alu_minu (uint32_t, uint32_t)` [Built-in Function]
Generated assembler `cv.minu`

`int32_t __builtin_riscv_cv_alu_max (int32_t, int32_t)` [Built-in Function]
Generated assembler `cv.max`

`uint32_tnt __builtin_riscv_cv_alu_maxu (uint32_t, uint32_t)` [Built-in Function]
Generated assembler `cv.maxu`

`int32_t __builtin_riscv_cv_alu_exths (int16_t)` [Built-in Function]
Generated assembler `cv.exths`

`uint32_t __builtin_riscv_cv_alu_exthz (uint16_t)` [Built-in Function]
Generated assembler `cv.exthz`

`int32_t __builtin_riscv_cv_alu_extbs (int8_t)` [Built-in Function]
Generated assembler `cv.extbs`

`uint32_t __builtin_riscv_cv_alu_extbz (uint8_t)` [Built-in Function]
Generated assembler `cv.extbz`

`int32_t __builtin_riscv_cv_alu_clip (int32_t, uint32_t)` [Built-in Function]

Generated assembler `cv.clip` if the uint32_t operand is a constant and an exact power of 2. Generated assembler `cv.clipr` if the it is a register.

`uint32_t __builtin_riscv_cv_alu_clipu (uint32_t, uint32_t)` [Built-in Function]

Generated assembler `cv.clipu` if the uint32_t operand is a constant and an exact power of 2. Generated assembler `cv.clipur` if the it is a register.

`int32_t __builtin_riscv_cv_alu_addN (int32_t, int32_t, uint8_t)` [Built-in Function]

Generated assembler `cv.addN` if the uint8_t operand is a constant and in the range 0 <= shft <= 31. Generated assembler `cv.addNr` if the it is a register.

`uint32_t __builtin_riscv_cv_alu_adduN (uint32_t, uint32_t, uint8_t)` [Built-in Function]

Generated assembler `cv.adduN` if the uint8_t operand is a constant and in the range 0 <= shft <= 31. Generated assembler `cv.adduNr` if the it is a register.

`int32_t __builtin_riscv_cv_alu_addRN (int32_t, int32_t, uint8_t)` [Built-in Function]

Generated assembler `cv.addRN` if the uint8_t operand is a constant and in the range 0 <= shft <= 31. Generated assembler `cv.addRNr` if the it is a register.

`uint32_t __builtin_riscv_cv_alu_adduRN (uint32_t, uint32_t, uint8_t)` [Built-in Function]

Generated assembler `cv.adduRN` if the uint8_t operand is a constant and in the range 0 <= shft <= 31. Generated assembler `cv.adduRNr` if the it is a register.

`int32_t __builtin_riscv_cv_alu_subN (int32_t, int32_t, uint8_t)` [Built-in Function]

Generated assembler `cv.subN` if the uint8_t operand is a constant and in the range 0 <= shft <= 31. Generated assembler `cv.subNr` if the it is a register.

`uint32_t __builtin_riscv_cv_alu_subuN (uint32_t, uint32_t, uint8_t)` [Built-in Function]

Generated assembler `cv.subuN` if the uint8_t operand is a constant and in the range 0 <= shft <= 31. Generated assembler `cv.subuNr` if the it is a register.

`int32_t __builtin_riscv_cv_alu_subRN (int32_t, int32_t, uint8_t)` [Built-in Function]

Generated assembler `cv.subRN` if the uint8_t operand is a constant and in the range 0 <= shft <= 31. Generated assembler `cv.subRNr` if the it is a register.

`uint32_t __builtin_riscv_cv_alu_subuRN (uint32_t, uint32_t, uint8_t)` [Built-in Function]

Generated assembler `cv.subuRN` if the uint8_t operand is a constant and in the range 0 <= shft <= 31. Generated assembler `cv.subuRNr` if the it is a register.

These built-in functions are available for the CORE-V Event Load machine architecture. For more information on CORE-V ELW builtins, please see https://github.com/openhwgroup/core-v-sw/blob/master/specifications/corev-builtin-spec.md#listing-of-event-load-word-builtins-xcvelw

`uint32_t __builtin_riscv_cv_elw_elw (uint32_t *)` [Built-in Function]
Generated assembler `cv.elw`

These built-in functions are available for the CORE-V SIMD machine architecture. For more information on CORE-V SIMD built-ins, please see https://github.com/openhwgroup/core-v-sw/blob/master/specifications/corev-builtin-spec.md#listing-of-pulp-816-bit-simd-builtins-xcvsimd

`uint32_t __builtin_riscv_cv_simd_add_h (uint32_t, uint32_t, uint4_t)` [Built-in Function]
Generated assembler `cv.add.h`

`uint32_t __builtin_riscv_cv_simd_add_b (uint32_t, uint32_t)` [Built-in Function]
Generated assembler `cv.add.b`

`uint32_t __builtin_riscv_cv_simd_add_sc_h (uint32_t, int16_t)` [Built-in Function]
Generated assembler `cv.add.sc.h`

`uint32_t __builtin_riscv_cv_simd_add_sc_h (uint32_t, int6_t)` [Built-in Function]
Generated assembler `cv.add.sci.h`

`uint32_t __builtin_riscv_cv_simd_add_sc_b (uint32_t, int8_t)` [Built-in Function]
Generated assembler `cv.add.sc.b`

`uint32_t __builtin_riscv_cv_simd_add_sc_b (uint32_t, int6_t)` [Built-in Function]
Generated assembler `cv.add.sci.b`

`uint32_t __builtin_riscv_cv_simd_sub_h (uint32_t, uint32_t, uint4_t)` [Built-in Function]
Generated assembler `cv.sub.h`

`uint32_t __builtin_riscv_cv_simd_sub_b (uint32_t, uint32_t)` [Built-in Function]
Generated assembler `cv.sub.b`

`uint32_t __builtin_riscv_cv_simd_sub_sc_h (uint32_t, int16_t)` [Built-in Function]
Generated assembler `cv.sub.sc.h`

`uint32_t __builtin_riscv_cv_simd_sub_sc_h (uint32_t, int6_t)` [Built-in Function]
Generated assembler `cv.sub.sci.h`

uint32_t __builtin_riscv_cv_simd_sub_sc_b (uint32_t, int8_t) [Built-in Function]
Generated assembler cv.sub.sc.b

uint32_t __builtin_riscv_cv_simd_sub_sc_b (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.sub.sci.b

uint32_t __builtin_riscv_cv_simd_avg_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.avg.h

uint32_t __builtin_riscv_cv_simd_avg_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.avg.b

uint32_t __builtin_riscv_cv_simd_avg_sc_h (uint32_t, int16_t) [Built-in Function]
Generated assembler cv.avg.sc.h

uint32_t __builtin_riscv_cv_simd_avg_sc_h (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.avg.sci.h

uint32_t __builtin_riscv_cv_simd_avg_sc_b (uint32_t, int8_t) [Built-in Function]
Generated assembler cv.avg.sc.b

uint32_t __builtin_riscv_cv_simd_avg_sc_b (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.avg.sci.b

uint32_t __builtin_riscv_cv_simd_avgu_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.avgu.h

uint32_t __builtin_riscv_cv_simd_avgu_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.avgu.b

uint32_t __builtin_riscv_cv_simd_avgu_sc_h (uint32_t, uint16_t) [Built-in Function]
Generated assembler cv.avgu.sc.h

uint32_t __builtin_riscv_cv_simd_avgu_sc_h (uint32_t, uint6_t) [Built-in Function]
Generated assembler cv.avgu.sci.h

uint32_t __builtin_riscv_cv_simd_avgu_sc_b (uint32_t, uint8_t) [Built-in Function]
Generated assembler cv.avgu.sc.b

uint32_t __builtin_riscv_cv_simd_avgu_sc_b (uint32_t, uint6_t) [Built-in Function]
Generated assembler cv.avgu.sci.b

uint32_t __builtin_riscv_cv_simd_min_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.min.h

uint32_t __builtin_riscv_cv_simd_min_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.min.b

uint32_t __builtin_riscv_cv_simd_min_sc_h (uint32_t, int16_t) [Built-in Function]
Generated assembler cv.min.sc.h

uint32_t __builtin_riscv_cv_simd_min_sc_h (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.min.sci.h

uint32_t __builtin_riscv_cv_simd_min_sc_b (uint32_t, int8_t) [Built-in Function]
Generated assembler cv.min.sc.b

uint32_t __builtin_riscv_cv_simd_min_sc_b (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.min.sci.b

uint32_t __builtin_riscv_cv_simd_minu_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.minu.h

uint32_t __builtin_riscv_cv_simd_minu_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.minu.b

uint32_t __builtin_riscv_cv_simd_minu_sc_h (uint32_t, uint16_t) [Built-in Function]
Generated assembler cv.minu.sc.h

uint32_t __builtin_riscv_cv_simd_minu_sc_h (uint32_t, uint6_t) [Built-in Function]
Generated assembler cv.minu.sci.h

uint32_t __builtin_riscv_cv_simd_minu_sc_b (uint32_t, uint8_t) [Built-in Function]
Generated assembler cv.minu.sc.b

uint32_t __builtin_riscv_cv_simd_minu_sc_b (uint32_t, uint6_t) [Built-in Function]
Generated assembler cv.minu.sci.b

`uint32_t __builtin_riscv_cv_simd_max_h (uint32_t, uint32_t)` [Built-in Function]
Generated assembler `cv.max.h`

`uint32_t __builtin_riscv_cv_simd_max_b (uint32_t, uint32_t)` [Built-in Function]
Generated assembler `cv.max.b`

`uint32_t __builtin_riscv_cv_simd_max_sc_h (uint32_t, int16_t)` [Built-in Function]
Generated assembler `cv.max.sc.h`

`uint32_t __builtin_riscv_cv_simd_max_sc_h (uint32_t, int6_t)` [Built-in Function]
Generated assembler `cv.max.sci.h`

`uint32_t __builtin_riscv_cv_simd_max_sc_b (uint32_t, int8_t)` [Built-in Function]
Generated assembler `cv.max.sc.b`

`uint32_t __builtin_riscv_cv_simd_max_sc_b (uint32_t, int6_t)` [Built-in Function]
Generated assembler `cv.max.sci.b`

`uint32_t __builtin_riscv_cv_simd_maxu_h (uint32_t, uint32_t)` [Built-in Function]
Generated assembler `cv.maxu.h`

`uint32_t __builtin_riscv_cv_simd_maxu_b (uint32_t, uint32_t)` [Built-in Function]
Generated assembler `cv.maxu.b`

`uint32_t __builtin_riscv_cv_simd_maxu_sc_h (uint32_t, uint16_t)` [Built-in Function]
Generated assembler `cv.maxu.sc.h`

`uint32_t __builtin_riscv_cv_simd_maxu_sc_h (uint32_t, uint6_t)` [Built-in Function]
Generated assembler `cv.maxu.sci.h`

`uint32_t __builtin_riscv_cv_simd_maxu_sc_b (uint32_t, uint8_t)` [Built-in Function]
Generated assembler `cv.maxu.sc.b`

`uint32_t __builtin_riscv_cv_simd_maxu_sc_b (uint32_t, uint6_t)` [Built-in Function]
Generated assembler `cv.maxu.sci.b`

`uint32_t __builtin_riscv_cv_simd_srl_h (uint32_t, uint32_t)` [Built-in Function]
Generated assembler `cv.srl.h`

uint32_t __builtin_riscv_cv_simd_srl_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.srl.b

uint32_t __builtin_riscv_cv_simd_srl_sc_h (uint32_t, int16_t) [Built-in Function]
Generated assembler cv.srl.sc.h

uint32_t __builtin_riscv_cv_simd_srl_sc_h (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.srl.sci.h

uint32_t __builtin_riscv_cv_simd_srl_sc_b (uint32_t, int8_t) [Built-in Function]
Generated assembler cv.srl.sc.b

uint32_t __builtin_riscv_cv_simd_srl_sc_b (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.srl.sci.b

uint32_t __builtin_riscv_cv_simd_sra_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.sra.h

uint32_t __builtin_riscv_cv_simd_sra_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.sra.b

uint32_t __builtin_riscv_cv_simd_sra_sc_h (uint32_t, int16_t) [Built-in Function]
Generated assembler cv.sra.sc.h

uint32_t __builtin_riscv_cv_simd_sra_sc_h (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.sra.sci.h

uint32_t __builtin_riscv_cv_simd_sra_sc_b (uint32_t, int8_t) [Built-in Function]
Generated assembler cv.sra.sc.b

uint32_t __builtin_riscv_cv_simd_sra_sc_b (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.sra.sci.b

uint32_t __builtin_riscv_cv_simd_sll_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.sll.h

uint32_t __builtin_riscv_cv_simd_sll_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.sll.b

uint32_t __builtin_riscv_cv_simd_sll_sc_h (uint32_t, int16_t) [Built-in Function]
Generated assembler cv.sll.sc.h

uint32_t __builtin_riscv_cv_simd_sll_sc_h (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.sll.sci.h

uint32_t __builtin_riscv_cv_simd_sll_sc_b (uint32_t, int8_t) [Built-in Function]
Generated assembler cv.sll.sc.b

uint32_t __builtin_riscv_cv_simd_sll_sc_b (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.sll.sci.b

uint32_t __builtin_riscv_cv_simd_or_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.or.h

uint32_t __builtin_riscv_cv_simd_or_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.or.b

uint32_t __builtin_riscv_cv_simd_or_sc_h (uint32_t, int16_t) [Built-in Function]
Generated assembler cv.or.sc.h

uint32_t __builtin_riscv_cv_simd_or_sc_h (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.or.sci.h

uint32_t __builtin_riscv_cv_simd_or_sc_b (uint32_t, int8_t) [Built-in Function]
Generated assembler cv.or.sc.b

uint32_t __builtin_riscv_cv_simd_or_sc_b (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.or.sci.b

uint32_t __builtin_riscv_cv_simd_xor_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.xor.h

uint32_t __builtin_riscv_cv_simd_xor_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.xor.b

uint32_t __builtin_riscv_cv_simd_xor_sc_h (uint32_t, int16_t) [Built-in Function]
Generated assembler cv.xor.sc.h

uint32_t __builtin_riscv_cv_simd_xor_sc_h (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.xor.sci.h

uint32_t __builtin_riscv_cv_simd_xor_sc_b (uint32_t, int8_t) [Built-in Function]
Generated assembler cv.xor.sc.b

uint32_t __builtin_riscv_cv_simd_xor_sc_b (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.xor.sci.b

uint32_t __builtin_riscv_cv_simd_and_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.and.h

uint32_t __builtin_riscv_cv_simd_and_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.and.b

uint32_t __builtin_riscv_cv_simd_and_sc_h (uint32_t, int16_t) [Built-in Function]
Generated assembler cv.and.sc.h

uint32_t __builtin_riscv_cv_simd_and_sc_h (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.and.sci.h

uint32_t __builtin_riscv_cv_simd_and_sc_b (uint32_t, int8_t) [Built-in Function]
Generated assembler cv.and.sc.b

uint32_t __builtin_riscv_cv_simd_and_sc_b (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.and.sci.b

uint32_t __builtin_riscv_cv_simd_abs_h (uint32_t) [Built-in Function]
Generated assembler cv.abs.h

uint32_t __builtin_riscv_cv_simd_abs_b (uint32_t) [Built-in Function]
Generated assembler cv.abs.b

uint32_t __builtin_riscv_cv_simd_dotup_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.dotup.h

uint32_t __builtin_riscv_cv_simd_dotup_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.dotup.b

uint32_t __builtin_riscv_cv_simd_dotup_sc_h (uint32_t, uint16_t) [Built-in Function]
Generated assembler cv.dotup.sc.h

uint32_t __builtin_riscv_cv_simd_dotup_sc_h (uint32_t, uint6_t) [Built-in Function]
Generated assembler cv.dotup.sci.h

uint32_t __builtin_riscv_cv_simd_dotup_sc_b (uint32_t, uint8_t) [Built-in Function]
Generated assembler cv.dotup.sc.b

uint32_t __builtin_riscv_cv_simd_dotup_sc_b (uint32_t, uint6_t) [Built-in Function]
Generated assembler cv.dotup.sci.b

uint32_t __builtin_riscv_cv_simd_dotusp_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.dotusp.h

uint32_t __builtin_riscv_cv_simd_dotusp_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.dotusp.b

uint32_t __builtin_riscv_cv_simd_dotusp_sc_h (uint32_t, int16_t) [Built-in Function]
Generated assembler cv.dotusp.sc.h

uint32_t __builtin_riscv_cv_simd_dotusp_sc_h (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.dotusp.sci.h

uint32_t __builtin_riscv_cv_simd_dotusp_sc_b (uint32_t, int8_t) [Built-in Function]
Generated assembler cv.dotusp.sc.b

uint32_t __builtin_riscv_cv_simd_dotusp_sc_b (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.dotusp.sci.b

uint32_t __builtin_riscv_cv_simd_dotsp_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.dotsp.h

uint32_t __builtin_riscv_cv_simd_dotsp_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.dotsp.b

uint32_t __builtin_riscv_cv_simd_dotsp_sc_h (uint32_t, int16_t) [Built-in Function]
Generated assembler cv.dotsp.sc.h

uint32_t __builtin_riscv_cv_simd_dotsp_sc_h (uint32_t, int6_t) [Built-in Function]
Generated assembler `cv.dotsp.sci.h`

uint32_t __builtin_riscv_cv_simd_dotsp_sc_b (uint32_t, int8_t) [Built-in Function]
Generated assembler `cv.dotsp.sc.b`

uint32_t __builtin_riscv_cv_simd_dotsp_sc_b (uint32_t, int6_t) [Built-in Function]
Generated assembler `cv.dotsp.sci.b`

uint32_t __builtin_riscv_cv_simd_sdotup_h (uint32_t, uint32_t, uint32_t) [Built-in Function]
Generated assembler `cv.sdotup.h`

uint32_t __builtin_riscv_cv_simd_sdotup_b (uint32_t, uint32_t, uint32_t) [Built-in Function]
Generated assembler `cv.sdotup.b`

uint32_t __builtin_riscv_cv_simd_sdotup_sc_h (uint32_t, uint16_t, uint32_t) [Built-in Function]
Generated assembler `cv.sdotup.sc.h`

uint32_t __builtin_riscv_cv_simd_sdotup_sc_h (uint32_t, uint6_t, uint32_t) [Built-in Function]
Generated assembler `cv.sdotup.sci.h`

uint32_t __builtin_riscv_cv_simd_sdotup_sc_b (uint32_t, uint8_t, uint32_t) [Built-in Function]
Generated assembler `cv.sdotup.sc.b`

uint32_t __builtin_riscv_cv_simd_sdotup_sc_b (uint32_t, uint6_t, uint32_t) [Built-in Function]
Generated assembler `cv.sdotup.sci.b`

uint32_t __builtin_riscv_cv_simd_sdotusp_h (uint32_t, uint32_t, uint32_t) [Built-in Function]
Generated assembler `cv.sdotusp.h`

uint32_t __builtin_riscv_cv_simd_sdotusp_b (uint32_t, uint32_t, uint32_t) [Built-in Function]
Generated assembler `cv.sdotusp.b`

uint32_t __builtin_riscv_cv_simd_sdotusp_sc_h (uint32_t, int16_t, uint32_t) [Built-in Function]
Generated assembler `cv.sdotusp.sc.h`

uint32_t __builtin_riscv_cv_simd_sdotusp_sc_h (uint32_t, int6_t, uint32_t) [Built-in Function]
Generated assembler `cv.sdotusp.sci.h`

`uint32_t __builtin_riscv_cv_simd_sdotusp_sc_b (uint32_t, int8_t, uint32_t)` [Built-in Function]
Generated assembler `cv.sdotusp.sc.b`

`uint32_t __builtin_riscv_cv_simd_sdotusp_sc_b (uint32_t, int6_t, uint32_t)` [Built-in Function]
Generated assembler `cv.sdotusp.sci.b`

`uint32_t __builtin_riscv_cv_simd_sdotsp_h (uint32_t, uint32_t, uint32_t)` [Built-in Function]
Generated assembler `cv.sdotsp.h`

`uint32_t __builtin_riscv_cv_simd_sdotsp_b (uint32_t, uint32_t, uint32_t)` [Built-in Function]
Generated assembler `cv.sdotsp.b`

`uint32_t __builtin_riscv_cv_simd_sdotsp_sc_h (uint32_t, int16_t, uint32_t)` [Built-in Function]
Generated assembler `cv.sdotsp.sc.h`

`uint32_t __builtin_riscv_cv_simd_sdotsp_sc_h (uint32_t, int6_t, uint32_t)` [Built-in Function]
Generated assembler `cv.sdotsp.sci.h`

`uint32_t __builtin_riscv_cv_simd_sdotsp_sc_b (uint32_t, int8_t, uint32_t)` [Built-in Function]
Generated assembler `cv.sdotsp.sc.b`

`uint32_t __builtin_riscv_cv_simd_sdotsp_sc_b (uint32_t, int6_t, uint32_t)` [Built-in Function]
Generated assembler `cv.sdotsp.sci.b`

`uint32_t __builtin_riscv_cv_simd_extract_h (uint32_t, uint6_t)` [Built-in Function]
Generated assembler `cv.extract.h`

`uint32_t __builtin_riscv_cv_simd_extract_b (uint32_t, uint6_t)` [Built-in Function]
Generated assembler `cv.extract.b`

`uint32_t __builtin_riscv_cv_simd_extractu_h (uint32_t, uint6_t)` [Built-in Function]
Generated assembler `cv.extractu.h`

`uint32_t __builtin_riscv_cv_simd_extractu_b (uint32_t, uint6_t)` [Built-in Function]
Generated assembler `cv.extractu.b`

`uint32_t __builtin_riscv_cv_simd_insert_h (uint32_t, uint32_t)` [Built-in Function]
Generated assembler `cv.insert.h`

uint32_t __builtin_riscv_cv_simd_insert_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.insert.b

uint32_t __builtin_riscv_cv_simd_shuffle_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.shuffle.h

uint32_t __builtin_riscv_cv_simd_shuffle_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.shuffle.b

uint32_t __builtin_riscv_cv_simd_shuffle_sci_h (uint32_t, uint4_t) [Built-in Function]
Generated assembler cv.shuffle.sci.h

uint32_t __builtin_riscv_cv_simd_shufflei0_sci_b (uint32_t, uint4_t) [Built-in Function]
Generated assembler cv.shufflei0.sci.b

uint32_t __builtin_riscv_cv_simd_shufflei1_sci_b (uint32_t, uint4_t) [Built-in Function]
Generated assembler cv.shufflei1.sci.b

uint32_t __builtin_riscv_cv_simd_shufflei2_sci_b (uint32_t, uint4_t) [Built-in Function]
Generated assembler cv.shufflei2.sci.b

uint32_t __builtin_riscv_cv_simd_shufflei3_sci_b (uint32_t, uint4_t) [Built-in Function]
Generated assembler cv.shufflei3.sci.b

uint32_t __builtin_riscv_cv_simd_shuffle2_h (uint32_t, uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.shuffle2.h

uint32_t __builtin_riscv_cv_simd_shuffle2_b (uint32_t, uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.shuffle2.b

uint32_t __builtin_riscv_cv_simd_packlo_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.pack

uint32_t __builtin_riscv_cv_simd_packhi_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.pack.h

uint32_t __builtin_riscv_cv_simd_packhi_b (uint32_t, uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.packhi.b

uint32_t __builtin_riscv_cv_simd_packlo_b (uint32_t, uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.packlo.b

uint32_t __builtin_riscv_cv_simd_cmpeq_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.cmpeq.h

uint32_t __builtin_riscv_cv_simd_cmpeq_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.cmpeq.b

uint32_t __builtin_riscv_cv_simd_cmpeq_sc_h (uint32_t, int16_t) [Built-in Function]
Generated assembler cv.cmpeq.sc.h

uint32_t __builtin_riscv_cv_simd_cmpeq_sc_h (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.cmpeq.sci.h

uint32_t __builtin_riscv_cv_simd_cmpeq_sc_b (uint32_t, int8_t) [Built-in Function]
Generated assembler cv.cmpeq.sc.b

uint32_t __builtin_riscv_cv_simd_cmpeq_sc_b (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.cmpeq.sci.b

uint32_t __builtin_riscv_cv_simd_cmpne_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.cmpne.h

uint32_t __builtin_riscv_cv_simd_cmpne_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.cmpne.b

uint32_t __builtin_riscv_cv_simd_cmpne_sc_h (uint32_t, int16_t) [Built-in Function]
Generated assembler cv.cmpne.sc.h

uint32_t __builtin_riscv_cv_simd_cmpne_sc_h (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.cmpne.sci.h

uint32_t __builtin_riscv_cv_simd_cmpne_sc_b (uint32_t, int8_t) [Built-in Function]
Generated assembler cv.cmpne.sc.b

uint32_t __builtin_riscv_cv_simd_cmpne_sc_b (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.cmpne.sci.b

uint32_t __builtin_riscv_cv_simd_cmpgt_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.cmpgt.h

uint32_t __builtin_riscv_cv_simd_cmpgt_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.cmpgt.b

uint32_t __builtin_riscv_cv_simd_cmpgt_sc_h (uint32_t, int16_t) [Built-in Function]
Generated assembler cv.cmpgt.sc.h

uint32_t __builtin_riscv_cv_simd_cmpgt_sc_h (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.cmpgt.sci.h

uint32_t __builtin_riscv_cv_simd_cmpgt_sc_b (uint32_t, int8_t) [Built-in Function]
Generated assembler cv.cmpgt.sc.b

uint32_t __builtin_riscv_cv_simd_cmpgt_sc_b (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.cmpgt.sci.b

uint32_t __builtin_riscv_cv_simd_cmpge_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.cmpge.h

uint32_t __builtin_riscv_cv_simd_cmpge_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.cmpge.b

uint32_t __builtin_riscv_cv_simd_cmpge_sc_h (uint32_t, int16_t) [Built-in Function]
Generated assembler cv.cmpge.sc.h

uint32_t __builtin_riscv_cv_simd_cmpge_sc_h (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.cmpge.sci.h

uint32_t __builtin_riscv_cv_simd_cmpge_sc_b (uint32_t, int8_t) [Built-in Function]
Generated assembler cv.cmpge.sc.b

uint32_t __builtin_riscv_cv_simd_cmpge_sc_b (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.cmpge.sci.b

uint32_t __builtin_riscv_cv_simd_cmplt_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.cmplt.h

uint32_t __builtin_riscv_cv_simd_cmplt_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.cmplt.b

uint32_t __builtin_riscv_cv_simd_cmplt_sc_h (uint32_t, int16_t) [Built-in Function]
Generated assembler cv.cmplt.sc.h

uint32_t __builtin_riscv_cv_simd_cmplt_sc_h (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.cmplt.sci.h

uint32_t __builtin_riscv_cv_simd_cmplt_sc_b (uint32_t, int8_t) [Built-in Function]
Generated assembler cv.cmplt.sc.b

uint32_t __builtin_riscv_cv_simd_cmplt_sc_b (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.cmplt.sci.b

uint32_t __builtin_riscv_cv_simd_cmple_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.cmple.h

uint32_t __builtin_riscv_cv_simd_cmple_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.cmple.b

uint32_t __builtin_riscv_cv_simd_cmple_sc_h (uint32_t, int16_t) [Built-in Function]
Generated assembler cv.cmple.sc.h

uint32_t __builtin_riscv_cv_simd_cmple_sc_h (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.cmple.sci.h

uint32_t __builtin_riscv_cv_simd_cmple_sc_b (uint32_t, int8_t) [Built-in Function]
Generated assembler cv.cmple.sc.b

uint32_t __builtin_riscv_cv_simd_cmple_sc_b (uint32_t, int6_t) [Built-in Function]
Generated assembler cv.cmple.sci.b

uint32_t __builtin_riscv_cv_simd_cmpgtu_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.cmpgtu.h

uint32_t __builtin_riscv_cv_simd_cmpgtu_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.cmpgtu.b

`uint32_t __builtin_riscv_cv_simd_cmpgtu_sc_h (uint32_t, uint16_t)` [Built-in Function]
Generated assembler `cv.cmpgtu.sc.h`

`uint32_t __builtin_riscv_cv_simd_cmpgtu_sc_h (uint32_t, uint6_t)` [Built-in Function]
Generated assembler `cv.cmpgtu.sci.h`

`uint32_t __builtin_riscv_cv_simd_cmpgtu_sc_b (uint32_t, uint8_t)` [Built-in Function]
Generated assembler `cv.cmpgtu.sc.b`

`uint32_t __builtin_riscv_cv_simd_cmpgtu_sc_b (uint32_t, uint6_t)` [Built-in Function]
Generated assembler `cv.cmpgtu.sci.b`

`uint32_t __builtin_riscv_cv_simd_cmpgeu_h (uint32_t, uint32_t)` [Built-in Function]
Generated assembler `cv.cmpgeu.h`

`uint32_t __builtin_riscv_cv_simd_cmpgeu_b (uint32_t, uint32_t)` [Built-in Function]
Generated assembler `cv.cmpgeu.b`

`uint32_t __builtin_riscv_cv_simd_cmpgeu_sc_h (uint32_t, uint16_t)` [Built-in Function]
Generated assembler `cv.cmpgeu.sc.h`

`uint32_t __builtin_riscv_cv_simd_cmpgeu_sc_h (uint32_t, uint6_t)` [Built-in Function]
Generated assembler `cv.cmpgeu.sci.h`

`uint32_t __builtin_riscv_cv_simd_cmpgeu_sc_b (uint32_t, uint8_t)` [Built-in Function]
Generated assembler `cv.cmpgeu.sc.b`

`uint32_t __builtin_riscv_cv_simd_cmpgeu_sc_b (uint32_t, uint6_t)` [Built-in Function]
Generated assembler `cv.cmpgeu.sci.b`

`uint32_t __builtin_riscv_cv_simd_cmpltu_h (uint32_t, uint32_t)` [Built-in Function]
Generated assembler `cv.cmpltu.h`

`uint32_t __builtin_riscv_cv_simd_cmpltu_b (uint32_t, uint32_t)` [Built-in Function]
Generated assembler `cv.cmpltu.b`

`uint32_t __builtin_riscv_cv_simd_cmpltu_sc_h (uint32_t, uint16_t)` [Built-in Function]
Generated assembler `cv.cmpltu.sc.h`

uint32_t __builtin_riscv_cv_simd_cmpltu_sc_h (uint32_t, uint6_t) [Built-in Function]
Generated assembler cv.cmpltu.sci.h

uint32_t __builtin_riscv_cv_simd_cmpltu_sc_b (uint32_t, uint8_t) [Built-in Function]
Generated assembler cv.cmpltu.sc.b

uint32_t __builtin_riscv_cv_simd_cmpltu_sc_b (uint32_t, uint6_t) [Built-in Function]
Generated assembler cv.cmpltu.sci.b

uint32_t __builtin_riscv_cv_simd_cmpleu_h (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.cmpleu.h

uint32_t __builtin_riscv_cv_simd_cmpleu_b (uint32_t, uint32_t) [Built-in Function]
Generated assembler cv.cmpleu.b

uint32_t __builtin_riscv_cv_simd_cmpleu_sc_h (uint32_t, uint16_t) [Built-in Function]
Generated assembler cv.cmpleu.sc.h

uint32_t __builtin_riscv_cv_simd_cmpleu_sc_h (uint32_t, uint6_t) [Built-in Function]
Generated assembler cv.cmpleu.sci.h

uint32_t __builtin_riscv_cv_simd_cmpleu_sc_b (uint32_t, uint8_t) [Built-in Function]
Generated assembler cv.cmpleu.sc.b

uint32_t __builtin_riscv_cv_simd_cmpleu_sc_b (uint32_t, uint6_t) [Built-in Function]
Generated assembler cv.cmpleu.sci.b

uint32_t __builtin_riscv_cv_simd_cplxmul_r (uint32_t, uint32_t, uint32_t, uint4_t) [Built-in Function]
Generated assembler cv.cplxmul.r

uint32_t __builtin_riscv_cv_simd_cplxmul_i (uint32_t, uint32_t, uint32_t, uint4_t) [Built-in Function]
Generated assembler cv.cplxmul.i

uint32_t __builtin_riscv_cv_simd_cplxmul_r (uint32_t, uint32_t, uint32_t, uint4_t) [Built-in Function]
Generated assembler cv.cplxmul.r.div2

uint32_t __builtin_riscv_cv_simd_cplxmul_i (uint32_t, uint32_t, uint32_t, uint4_t) [Built-in Function]
Generated assembler cv.cplxmul.i.div2

uint32_t __builtin_riscv_cv_simd_cplxmul_r (uint32_t, uint32_t, uint32_t, uint4_t) [Built-in Function]
Generated assembler `cv.cplxmul.r.div4`

uint32_t __builtin_riscv_cv_simd_cplxmul_i (uint32_t, uint32_t, uint32_t, uint4_t) [Built-in Function]
Generated assembler `cv.cplxmul.i.div4`

uint32_t __builtin_riscv_cv_simd_cplxmul_r (uint32_t, uint32_t, uint32_t, uint4_t) [Built-in Function]
Generated assembler `cv.cplxmul.r.div8`

uint32_t __builtin_riscv_cv_simd_cplxmul_i (uint32_t, uint32_t, uint32_t, uint4_t) [Built-in Function]
Generated assembler `cv.cplxmul.i.div8`

uint32_t __builtin_riscv_cv_simd_cplxconj (uint32_t) [Built-in Function]
Generated assembler `cv.cplxconj`

uint32_t __builtin_riscv_cv_simd_subrotmj (uint32_t, uint32_t, uint4_t) [Built-in Function]
Generated assembler `cv.subrotmj`

uint32_t __builtin_riscv_cv_simd_subrotmj (uint32_t, uint32_t, uint32_t, uint4_t) [Built-in Function]
Generated assembler `cv.subrotmj.div2`

uint32_t __builtin_riscv_cv_simd_subrotmj (uint32_t, uint32_t, uint32_t, uint4_t) [Built-in Function]
Generated assembler `cv.subrotmj.div4`

uint32_t __builtin_riscv_cv_simd_subrotmj (uint32_t, uint32_t, uint32_t, uint4_t) [Built-in Function]
Generated assembler `cv.subrotmj.div8`

uint32_t __builtin_riscv_cv_simd_add_h (uint32_t, uint32_t, uint32_t, uint4_t) [Built-in Function]
Generated assembler `cv.add.div2`

uint32_t __builtin_riscv_cv_simd_add_h (uint32_t, uint32_t, uint32_t, uint4_t) [Built-in Function]
Generated assembler `cv.add.div4`

uint32_t __builtin_riscv_cv_simd_add_h (uint32_t, uint32_t, uint32_t, uint4_t) [Built-in Function]
Generated assembler `cv.add.div8`

uint32_t __builtin_riscv_cv_simd_sub_h (uint32_t, uint32_t, uint32_t, uint4_t) [Built-in Function]
Generated assembler `cv.sub.div2`

`uint32_t __builtin_riscv_cv_simd_sub_h (uint32_t, uint32_t, uint32_t, uint4_t)` [Built-in Function]
Generated assembler `cv.sub.div4`

`uint32_t __builtin_riscv_cv_simd_sub_h (uint32_t, uint32_t, uint32_t, uint4_t)` [Built-in Function]
Generated assembler `cv.sub.div8`

7.13.32 RX Built-in Functions

GCC supports some of the RX instructions which cannot be expressed in the C programming language via the use of built-in functions. The following functions are supported:

`void __builtin_rx_brk (void)` [Built-in Function]
Generates the `brk` machine instruction.

`void __builtin_rx_clrpsw (int)` [Built-in Function]
Generates the `clrpsw` machine instruction to clear the specified bit in the processor status word.

`void __builtin_rx_int (int)` [Built-in Function]
Generates the `int` machine instruction to generate an interrupt with the specified value.

`void __builtin_rx_machi (int, int)` [Built-in Function]
Generates the `machi` machine instruction to add the result of multiplying the top 16 bits of the two arguments into the accumulator.

`void __builtin_rx_maclo (int, int)` [Built-in Function]
Generates the `maclo` machine instruction to add the result of multiplying the bottom 16 bits of the two arguments into the accumulator.

`void __builtin_rx_mulhi (int, int)` [Built-in Function]
Generates the `mulhi` machine instruction to place the result of multiplying the top 16 bits of the two arguments into the accumulator.

`void __builtin_rx_mullo (int, int)` [Built-in Function]
Generates the `mullo` machine instruction to place the result of multiplying the bottom 16 bits of the two arguments into the accumulator.

`int __builtin_rx_mvfachi (void)` [Built-in Function]
Generates the `mvfachi` machine instruction to read the top 32 bits of the accumulator.

`int __builtin_rx_mvfacmi (void)` [Built-in Function]
Generates the `mvfacmi` machine instruction to read the middle 32 bits of the accumulator.

`int __builtin_rx_mvfc (int)` [Built-in Function]
Generates the `mvfc` machine instruction which reads the control register specified in its argument and returns its value.

`void __builtin_rx_mvtachi (int)` [Built-in Function]
: Generates the `mvtachi` machine instruction to set the top 32 bits of the accumulator.

`void __builtin_rx_mvtaclo (int)` [Built-in Function]
: Generates the `mvtaclo` machine instruction to set the bottom 32 bits of the accumulator.

`void __builtin_rx_mvtc (int reg, int val)` [Built-in Function]
: Generates the `mvtc` machine instruction which sets control register number `reg` to `val`.

`void __builtin_rx_mvtipl (int)` [Built-in Function]
: Generates the `mvtipl` machine instruction set the interrupt priority level.

`void __builtin_rx_racw (int)` [Built-in Function]
: Generates the `racw` machine instruction to round the accumulator according to the specified mode.

`int __builtin_rx_revw (int)` [Built-in Function]
: Generates the `revw` machine instruction which swaps the bytes in the argument so that bits 0–7 now occupy bits 8–15 and vice versa, and also bits 16–23 occupy bits 24–31 and vice versa.

`void __builtin_rx_rmpa (void)` [Built-in Function]
: Generates the `rmpa` machine instruction which initiates a repeated multiply and accumulate sequence.

`void __builtin_rx_round (float)` [Built-in Function]
: Generates the `round` machine instruction which returns the floating-point argument rounded according to the current rounding mode set in the floating-point status word register.

`int __builtin_rx_sat (int)` [Built-in Function]
: Generates the `sat` machine instruction which returns the saturated value of the argument.

`void __builtin_rx_setpsw (int)` [Built-in Function]
: Generates the `setpsw` machine instruction to set the specified bit in the processor status word.

`void __builtin_rx_wait (void)` [Built-in Function]
: Generates the `wait` machine instruction.

7.13.33 S/390 System z Built-in Functions

`int __builtin_tbegin (void*)` [Built-in Function]
: Generates the `tbegin` machine instruction starting a non-constrained hardware transaction. If the parameter is non-NULL the memory area is used to store the transaction diagnostic buffer and will be passed as first operand to `tbegin`. This buffer can be defined using the `struct __htm_tdb` C struct defined in `htmintrin.h` and must reside on a double-word boundary. The second tbegin operand is set to `0xff0c`. This

enables save/restore of all GPRs and disables aborts for FPR and AR manipulations inside the transaction body. The condition code set by the tbegin instruction is returned as integer value. The tbegin instruction by definition overwrites the content of all FPRs. The compiler will generate code which saves and restores the FPRs. For soft-float code it is recommended to used the `*_nofloat` variant. In order to prevent a TDB from being written it is required to pass a constant zero value as parameter. Passing a zero value through a variable is not sufficient. Although modifications of access registers inside the transaction will not trigger an transaction abort it is not supported to actually modify them. Access registers do not get saved when entering a transaction. They will have undefined state when reaching the abort code.

Macros for the possible return codes of tbegin are defined in the `htmintrin.h` header file:

`_HTM_TBEGIN_STARTED` [Macro]

`tbegin` has been executed as part of normal processing. The transaction body is supposed to be executed.

`_HTM_TBEGIN_INDETERMINATE` [Macro]

The transaction was aborted due to an indeterminate condition which might be persistent.

`_HTM_TBEGIN_TRANSIENT` [Macro]

The transaction aborted due to a transient failure. The transaction should be re-executed in that case.

`_HTM_TBEGIN_PERSISTENT` [Macro]

The transaction aborted due to a persistent failure. Re-execution under same circumstances will not be productive.

`_HTM_FIRST_USER_ABORT_CODE` [Macro]

The `_HTM_FIRST_USER_ABORT_CODE` defined in `htmintrin.h` specifies the first abort code which can be used for `__builtin_tabort`. Values below this threshold are reserved for machine use.

`struct __htm_tdb` [Data type]

The `struct __htm_tdb` defined in `htmintrin.h` describes the structure of the transaction diagnostic block as specified in the Principles of Operation manual chapter 5-91.

`int __builtin_tbegin_nofloat (void*)` [Built-in Function]

Same as `__builtin_tbegin` but without FPR saves and restores. Using this variant in code making use of FPRs will leave the FPRs in undefined state when entering the transaction abort handler code.

`int __builtin_tbegin_retry (void*, int)` [Built-in Function]

In addition to `__builtin_tbegin` a loop for transient failures is generated. If tbegin returns a condition code of 2 the transaction will be retried as often as specified in the second argument. The perform processor assist instruction is used to tell the CPU about the number of fails so far.

`int __builtin_tbegin_retry_nofloat (void*, int)` [Built-in Function]

Same as `__builtin_tbegin_retry` but without FPR saves and restores. Using this variant in code making use of FPRs will leave the FPRs in undefined state when entering the transaction abort handler code.

`void __builtin_tbeginc (void)` [Built-in Function]

Generates the `tbeginc` machine instruction starting a constrained hardware transaction. The second operand is set to `0xff08`.

`int __builtin_tend (void)` [Built-in Function]

Generates the `tend` machine instruction finishing a transaction and making the changes visible to other threads. The condition code generated by tend is returned as integer value.

`void __builtin_tabort (int)` [Built-in Function]

Generates the `tabort` machine instruction with the specified abort code. Abort codes from 0 through 255 are reserved and will result in an error message.

`void __builtin_tx_assist (int)` [Built-in Function]

Generates the `ppa rX,rY,1` machine instruction. Where the integer parameter is loaded into rX and a value of zero is loaded into rY. The integer parameter specifies the number of times the transaction repeatedly aborted.

`int __builtin_tx_nesting_depth (void)` [Built-in Function]

Generates the `etnd` machine instruction. The current nesting depth is returned as integer value. For a nesting depth of 0 the code is not executed as part of an transaction.

`void __builtin_non_tx_store (uint64_t *, uint64_t)` [Built-in Function]

Generates the `ntstg` machine instruction. The second argument is written to the first arguments location. The store operation will not be rolled-back in case of an transaction abort.

7.13.34 SH Built-in Functions

The following built-in functions are supported on the SH1, SH2, SH3 and SH4 families of processors:

`void __builtin_set_thread_pointer (void *`*ptr*`)` [Built-in Function]

Sets the '`GBR`' register to the specified value *ptr*. This is usually used by system code that manages threads and execution contexts. The compiler normally does not generate code that modifies the contents of '`GBR`' and thus the value is preserved across function calls. Changing the '`GBR`' value in user code must be done with caution, since the compiler might use '`GBR`' in order to access thread local variables.

`void * __builtin_thread_pointer (void)` [Built-in Function]

Returns the value that is currently set in the '`GBR`' register. Memory loads and stores that use the thread pointer as a base address are turned into '`GBR`' based displacement loads and stores, if possible. For example:

```
struct my_tcb
```

```
{
   int a, b, c, d, e;
};

int get_tcb_value (void)
{
  // Generate 'mov.l @(8,gbr),r0' instruction
  return ((my_tcb*)__builtin_thread_pointer ())->c;
}
```

`unsigned int __builtin_sh_get_fpscr (void)` [Built-in Function]

Returns the value that is currently set in the 'FPSCR' register.

`void __builtin_sh_set_fpscr (unsigned int val)` [Built-in Function]

Sets the 'FPSCR' register to the specified value *val*, while preserving the current values of the FR, SZ and PR bits.

7.13.35 SPARC VIS Built-in Functions

GCC supports SIMD operations on the SPARC using both the generic vector extensions (see Section 7.8 [Vector Extensions], page 850) as well as built-in functions for the SPARC Visual Instruction Set (VIS). When you use the `-mvis` switch, the VIS extension is exposed as the following built-in functions:

```
typedef int v1si __attribute__ ((vector_size (4)));
typedef int v2si __attribute__ ((vector_size (8)));
typedef short v4hi __attribute__ ((vector_size (8)));
typedef short v2hi __attribute__ ((vector_size (4)));
typedef unsigned char v8qi __attribute__ ((vector_size (8)));
typedef unsigned char v4qi __attribute__ ((vector_size (4)));

void __builtin_vis_write_gsr (int64_t);
int64_t __builtin_vis_read_gsr (void);

void * __builtin_vis_alignaddr (void *, long);
void * __builtin_vis_alignaddrl (void *, long);
int64_t __builtin_vis_faligndatadi (int64_t, int64_t);
v2si __builtin_vis_faligndatav2si (v2si, v2si);
v4hi __builtin_vis_faligndatav4hi (v4si, v4si);
v8qi __builtin_vis_faligndatav8qi (v8qi, v8qi);

v4hi __builtin_vis_fexpand (v4qi);

v4hi __builtin_vis_fmul8x16 (v4qi, v4hi);
v4hi __builtin_vis_fmul8x16au (v4qi, v2hi);
v4hi __builtin_vis_fmul8x16al (v4qi, v2hi);
v4hi __builtin_vis_fmul8sux16 (v8qi, v4hi);
v4hi __builtin_vis_fmul8ulx16 (v8qi, v4hi);
v2si __builtin_vis_fmuld8sux16 (v4qi, v2hi);
v2si __builtin_vis_fmuld8ulx16 (v4qi, v2hi);

v4qi __builtin_vis_fpack16 (v4hi);
v8qi __builtin_vis_fpack32 (v2si, v8qi);
v2hi __builtin_vis_fpackfix (v2si);
v8qi __builtin_vis_fpmerge (v4qi, v4qi);

int64_t __builtin_vis_pdist (v8qi, v8qi, int64_t);
```

```
long __builtin_vis_edge8 (void *, void *);
long __builtin_vis_edge8l (void *, void *);
long __builtin_vis_edge16 (void *, void *);
long __builtin_vis_edge16l (void *, void *);
long __builtin_vis_edge32 (void *, void *);
long __builtin_vis_edge32l (void *, void *);

long __builtin_vis_fcmple16 (v4hi, v4hi);
long __builtin_vis_fcmple32 (v2si, v2si);
long __builtin_vis_fcmpne16 (v4hi, v4hi);
long __builtin_vis_fcmpne32 (v2si, v2si);
long __builtin_vis_fcmpgt16 (v4hi, v4hi);
long __builtin_vis_fcmpgt32 (v2si, v2si);
long __builtin_vis_fcmpeq16 (v4hi, v4hi);
long __builtin_vis_fcmpeq32 (v2si, v2si);

v4hi __builtin_vis_fpadd16 (v4hi, v4hi);
v2hi __builtin_vis_fpadd16s (v2hi, v2hi);
v2si __builtin_vis_fpadd32 (v2si, v2si);
v1si __builtin_vis_fpadd32s (v1si, v1si);
v4hi __builtin_vis_fpsub16 (v4hi, v4hi);
v2hi __builtin_vis_fpsub16s (v2hi, v2hi);
v2si __builtin_vis_fpsub32 (v2si, v2si);
v1si __builtin_vis_fpsub32s (v1si, v1si);

long __builtin_vis_array8 (long, long);
long __builtin_vis_array16 (long, long);
long __builtin_vis_array32 (long, long);
```

When you use the `-mvis2` switch, the VIS version 2.0 built-in functions also become available:

```
long __builtin_vis_bmask (long, long);
int64_t __builtin_vis_bshuffledi (int64_t, int64_t);
v2si __builtin_vis_bshufflev2si (v2si, v2si);
v4hi __builtin_vis_bshufflev2si (v4hi, v4hi);
v8qi __builtin_vis_bshufflev2si (v8qi, v8qi);

long __builtin_vis_edge8n (void *, void *);
long __builtin_vis_edge8ln (void *, void *);
long __builtin_vis_edge16n (void *, void *);
long __builtin_vis_edge16ln (void *, void *);
long __builtin_vis_edge32n (void *, void *);
long __builtin_vis_edge32ln (void *, void *);
```

When you use the `-mvis3` switch, the VIS version 3.0 built-in functions also become available:

```
void __builtin_vis_cmask8 (long);
void __builtin_vis_cmask16 (long);
void __builtin_vis_cmask32 (long);

v4hi __builtin_vis_fchksm16 (v4hi, v4hi);

v4hi __builtin_vis_fsll16 (v4hi, v4hi);
v4hi __builtin_vis_fslas16 (v4hi, v4hi);
v4hi __builtin_vis_fsrl16 (v4hi, v4hi);
v4hi __builtin_vis_fsra16 (v4hi, v4hi);
v2si __builtin_vis_fsll16 (v2si, v2si);
```

```
v2si __builtin_vis_fslas16 (v2si, v2si);
v2si __builtin_vis_fsrl16 (v2si, v2si);
v2si __builtin_vis_fsra16 (v2si, v2si);

long __builtin_vis_pdistn (v8qi, v8qi);

v4hi __builtin_vis_fmean16 (v4hi, v4hi);

int64_t __builtin_vis_fpadd64 (int64_t, int64_t);
int64_t __builtin_vis_fpsub64 (int64_t, int64_t);

v4hi __builtin_vis_fpadds16 (v4hi, v4hi);
v2hi __builtin_vis_fpadds16s (v2hi, v2hi);
v4hi __builtin_vis_fpsubs16 (v4hi, v4hi);
v2hi __builtin_vis_fpsubs16s (v2hi, v2hi);
v2si __builtin_vis_fpadds32 (v2si, v2si);
v1si __builtin_vis_fpadds32s (v1si, v1si);
v2si __builtin_vis_fpsubs32 (v2si, v2si);
v1si __builtin_vis_fpsubs32s (v1si, v1si);

long __builtin_vis_fucmple8 (v8qi, v8qi);
long __builtin_vis_fucmpne8 (v8qi, v8qi);
long __builtin_vis_fucmpgt8 (v8qi, v8qi);
long __builtin_vis_fucmpeq8 (v8qi, v8qi);

float __builtin_vis_fhadds (float, float);
double __builtin_vis_fhaddd (double, double);
float __builtin_vis_fhsubs (float, float);
double __builtin_vis_fhsubd (double, double);
float __builtin_vis_fnhadds (float, float);
double __builtin_vis_fnhaddd (double, double);

int64_t __builtin_vis_umulxhi (int64_t, int64_t);
int64_t __builtin_vis_xmulx (int64_t, int64_t);
int64_t __builtin_vis_xmulxhi (int64_t, int64_t);
```

When you use the `-mvis4` switch, the VIS version 4.0 built-in functions also become available:

```
v8qi __builtin_vis_fpadd8 (v8qi, v8qi);
v8qi __builtin_vis_fpadds8 (v8qi, v8qi);
v8qi __builtin_vis_fpaddus8 (v8qi, v8qi);
v4hi __builtin_vis_fpaddus16 (v4hi, v4hi);

v8qi __builtin_vis_fpsub8 (v8qi, v8qi);
v8qi __builtin_vis_fpsubs8 (v8qi, v8qi);
v8qi __builtin_vis_fpsubus8 (v8qi, v8qi);
v4hi __builtin_vis_fpsubus16 (v4hi, v4hi);

long __builtin_vis_fpcmple8 (v8qi, v8qi);
long __builtin_vis_fpcmpgt8 (v8qi, v8qi);
long __builtin_vis_fpcmpule16 (v4hi, v4hi);
long __builtin_vis_fpcmpugt16 (v4hi, v4hi);
long __builtin_vis_fpcmpule32 (v2si, v2si);
long __builtin_vis_fpcmpugt32 (v2si, v2si);

v8qi __builtin_vis_fpmax8 (v8qi, v8qi);
v4hi __builtin_vis_fpmax16 (v4hi, v4hi);
v2si __builtin_vis_fpmax32 (v2si, v2si);
```

```
v8qi __builtin_vis_fpmaxu8 (v8qi, v8qi);
v4hi __builtin_vis_fpmaxu16 (v4hi, v4hi);
v2si __builtin_vis_fpmaxu32 (v2si, v2si);

v8qi __builtin_vis_fpmin8 (v8qi, v8qi);
v4hi __builtin_vis_fpmin16 (v4hi, v4hi);
v2si __builtin_vis_fpmin32 (v2si, v2si);

v8qi __builtin_vis_fpminu8 (v8qi, v8qi);
v4hi __builtin_vis_fpminu16 (v4hi, v4hi);
v2si __builtin_vis_fpminu32 (v2si, v2si);
```

When you use the `-mvis4b` switch, the VIS version 4.0B built-in functions also become available:

```
v8qi __builtin_vis_dictunpack8 (double, int);
v4hi __builtin_vis_dictunpack16 (double, int);
v2si __builtin_vis_dictunpack32 (double, int);

long __builtin_vis_fpcmple8shl (v8qi, v8qi, int);
long __builtin_vis_fpcmpgt8shl (v8qi, v8qi, int);
long __builtin_vis_fpcmpeq8shl (v8qi, v8qi, int);
long __builtin_vis_fpcmpne8shl (v8qi, v8qi, int);

long __builtin_vis_fpcmple16shl (v4hi, v4hi, int);
long __builtin_vis_fpcmpgt16shl (v4hi, v4hi, int);
long __builtin_vis_fpcmpeq16shl (v4hi, v4hi, int);
long __builtin_vis_fpcmpne16shl (v4hi, v4hi, int);

long __builtin_vis_fpcmple32shl (v2si, v2si, int);
long __builtin_vis_fpcmpgt32shl (v2si, v2si, int);
long __builtin_vis_fpcmpeq32shl (v2si, v2si, int);
long __builtin_vis_fpcmpne32shl (v2si, v2si, int);

long __builtin_vis_fpcmpule8shl (v8qi, v8qi, int);
long __builtin_vis_fpcmpugt8shl (v8qi, v8qi, int);
long __builtin_vis_fpcmpule16shl (v4hi, v4hi, int);
long __builtin_vis_fpcmpugt16shl (v4hi, v4hi, int);
long __builtin_vis_fpcmpule32shl (v2si, v2si, int);
long __builtin_vis_fpcmpugt32shl (v2si, v2si, int);

long __builtin_vis_fpcmpde8shl (v8qi, v8qi, int);
long __builtin_vis_fpcmpde16shl (v4hi, v4hi, int);
long __builtin_vis_fpcmpde32shl (v2si, v2si, int);

long __builtin_vis_fpcmpur8shl (v8qi, v8qi, int);
long __builtin_vis_fpcmpur16shl (v4hi, v4hi, int);
long __builtin_vis_fpcmpur32shl (v2si, v2si, int);
```

7.13.36 TI C6X Built-in Functions

GCC provides intrinsics to access certain instructions of the TI C6X processors. These intrinsics, listed below, are available after inclusion of the `c6x_intrinsics.h` header file. They map directly to C6X instructions.

```
int _sadd (int, int);
int _ssub (int, int);
int _sadd2 (int, int);
int _ssub2 (int, int);
```

```
long long _mpy2 (int, int);
long long _smpy2 (int, int);
int _add4 (int, int);
int _sub4 (int, int);
int _saddu4 (int, int);

int _smpy (int, int);
int _smpyh (int, int);
int _smpyhl (int, int);
int _smpylh (int, int);

int _sshl (int, int);
int _subc (int, int);

int _avg2 (int, int);
int _avgu4 (int, int);

int _clrr (int, int);
int _extr (int, int);
int _extru (int, int);
int _abs (int);
int _abs2 (int);
```

7.13.37 x86 Built-in Functions

These built-in functions are available for the x86-32 and x86-64 family of computers, depending on the command-line switches used.

If you specify command-line switches such as `-msse`, the compiler could use the extended instruction sets even if the built-ins are not used explicitly in the program. For this reason, applications that perform run-time CPU detection must compile separate files for each supported architecture, using the appropriate flags. In particular, the file containing the CPU detection code should be compiled without these options.

The following machine modes are available for use with MMX built-in functions (see Section 7.8 [Vector Extensions], page 850): `V2SI` for a vector of two 32-bit integers, `V4HI` for a vector of four 16-bit integers, and `V8QI` for a vector of eight 8-bit integers. Some of the built-in functions operate on MMX registers as a whole 64-bit entity, these use `V1DI` as their mode.

If 3DNow! extensions are enabled, `V2SF` is used as a mode for a vector of two 32-bit floating-point values.

If SSE extensions are enabled, `V4SF` is used for a vector of four 32-bit floating-point values. Some instructions use a vector of four 32-bit integers, these use `V4SI`. Finally, some instructions operate on an entire vector register, interpreting it as a 128-bit integer, these use mode `TI`.

The x86-32 and x86-64 family of processors use additional built-in functions for efficient use of `TF` (`__float128`) 128-bit floating point and `TC` 128-bit complex floating-point values.

The following floating-point built-in functions are always available:

`__float128 __builtin_fabsq (__float128 x))` [Built-in Function]

Computes the absolute value of *x*.

`__float128 __builtin_copysignq (__float128 x, __float128 y)` [Built-in Function]
: Copies the sign of *y* into *x* and returns the new value of *x*.

`__float128 __builtin_infq (void)` [Built-in Function]
: Similar to `__builtin_inf`, except the return type is `__float128`.

`__float128 __builtin_huge_valq (void)` [Built-in Function]
: Similar to `__builtin_huge_val`, except the return type is `__float128`.

`__float128 __builtin_nanq (void)` [Built-in Function]
: Similar to `__builtin_nan`, except the return type is `__float128`.

`__float128 __builtin_nansq (void)` [Built-in Function]
: Similar to `__builtin_nans`, except the return type is `__float128`.

The following built-in function is always available.

`void __builtin_ia32_pause (void)` [Built-in Function]
: Generates the `pause` machine instruction with a compiler memory barrier.

The following built-in functions are always available and can be used to check the target platform type.

`void __builtin_cpu_init (void)` [Built-in Function]
: This function runs the CPU detection code to check the type of CPU and the features supported. This built-in function needs to be invoked along with the built-in functions to check CPU type and features, `__builtin_cpu_is` and `__builtin_cpu_supports`, only when used in a function that is executed before any constructors are called. The CPU detection code is automatically executed in a very high priority constructor.

For example, this function has to be used in `ifunc` resolvers that check for CPU type using the built-in functions `__builtin_cpu_is` and `__builtin_cpu_supports`, or in constructors on targets that don't support constructor priority.

```
static void (*resolve_memcpy (void)) (void)
{
  // ifunc resolvers fire before constructors, explicitly call the init
  // function.
  __builtin_cpu_init ();
  if (__builtin_cpu_supports ("ssse3"))
    return ssse3_memcpy; // super fast memcpy with ssse3 instructions.
  else
    return default_memcpy;
}

void *memcpy (void *, const void *, size_t)
     __attribute__ ((ifunc ("resolve_memcpy")));
```

`int __builtin_cpu_is (const char *cpuname)` [Built-in Function]
: This function returns a positive integer if the run-time CPU is of type *cpuname* and returns `0` otherwise. The following CPU names can be detected:

'`amd`' AMD CPU.

'intel' Intel CPU.

'atom' Intel Atom CPU.

'slm' Intel Silvermont CPU.

'core2' Intel Core 2 CPU.

'corei7' Intel Core i7 CPU.

'nehalem' Intel Core i7 Nehalem CPU.

'westmere'
Intel Core i7 Westmere CPU.

'sandybridge'
Intel Core i7 Sandy Bridge CPU.

'ivybridge'
Intel Core i7 Ivy Bridge CPU.

'haswell' Intel Core i7 Haswell CPU.

'broadwell'
Intel Core i7 Broadwell CPU.

'skylake' Intel Core i7 Skylake CPU.

'skylake-avx512'
Intel Core i7 Skylake AVX512 CPU.

'cannonlake'
Intel Core i7 Cannon Lake CPU.

'icelake-client'
Intel Core i7 Ice Lake Client CPU.

'icelake-server'
Intel Core i7 Ice Lake Server CPU.

'cascadelake'
Intel Core i7 Cascadelake CPU.

'tigerlake'
Intel Core i7 Tigerlake CPU.

'cooperlake'
Intel Core i7 Cooperlake CPU.

'sapphirerapids'
Intel Core i7 sapphirerapids CPU.

'alderlake'
Intel Core i7 Alderlake CPU.

'rocketlake'
Intel Core i7 Rocketlake CPU.

'graniterapids'
Intel Core i7 graniterapids CPU.

'graniterapids-d'
: Intel Core i7 graniterapids D CPU.

'arrowlake'
: Intel Core i7 Arrow Lake CPU.

'arrowlake-s'
: Intel Core i7 Arrow Lake S CPU.

'pantherlake'
: Intel Core i7 Panther Lake CPU.

'diamondrapids'
: Intel Core i7 Diamond Rapids CPU.

'novalake'
: Intel Core i7 Nova Lake CPU.

'bonnell' Intel Atom Bonnell CPU.

'silvermont'
: Intel Atom Silvermont CPU.

'goldmont'
: Intel Atom Goldmont CPU.

'goldmont-plus'
: Intel Atom Goldmont Plus CPU.

'tremont' Intel Atom Tremont CPU.

'sierraforest'
: Intel Atom Sierra Forest CPU.

'grandridge'
: Intel Atom Grand Ridge CPU.

'clearwaterforest'
: Intel Atom Clearwater Forest CPU.

'lujiazui'
: ZHAOXIN lujiazui CPU.

'yongfeng'
: ZHAOXIN yongfeng CPU.

'shijidadao'
: ZHAOXIN shijidadao CPU.

'amdfam10h'
: AMD Family 10h CPU.

'barcelona'
: AMD Family 10h Barcelona CPU.

'shanghai'
: AMD Family 10h Shanghai CPU.

'istanbul'
: AMD Family 10h Istanbul CPU.

'btver1' AMD Family 14h CPU.

'amdfam15h'
: AMD Family 15h CPU.

'bdver1' AMD Family 15h Bulldozer version 1.

'bdver2' AMD Family 15h Bulldozer version 2.

'bdver3' AMD Family 15h Bulldozer version 3.

'bdver4' AMD Family 15h Bulldozer version 4.

'btver2' AMD Family 16h CPU.

'amdfam17h'
: AMD Family 17h CPU.

'znver1' AMD Family 17h Zen version 1.

'znver2' AMD Family 17h Zen version 2.

'amdfam19h'
: AMD Family 19h CPU.

'znver3' AMD Family 19h Zen version 3.

'znver4' AMD Family 19h Zen version 4.

'znver5' AMD Family 1ah Zen version 5.

Here is an example:

```
if (__builtin_cpu_is ("corei7"))
  {
     do_corei7 (); // Core i7 specific implementation.
  }
else
  {
     do_generic (); // Generic implementation.
  }
```

`int __builtin_cpu_supports (const char *`*feature*`)` [Built-in Function]

This function returns a positive integer if the run-time CPU supports *feature* and returns `0` otherwise. The following features can be detected:

'cmov' CMOV instruction.

'mmx' MMX instructions.

'popcnt' POPCNT instruction.

'sse' SSE instructions.

'sse2' SSE2 instructions.

'sse3' SSE3 instructions.

'ssse3' SSSE3 instructions.

'sse4.1' SSE4.1 instructions.

'sse4.2' SSE4.2 instructions.

'avx' AVX instructions.

'avx2' AVX2 instructions.

'sse4a' SSE4A instructions.

'fma4' FMA4 instructions.

'xop' XOP instructions.

'fma' FMA instructions.

'avx512f' AVX512F instructions.

'bmi' BMI instructions.

'bmi2' BMI2 instructions.

'aes' AES instructions.

'pclmul' PCLMUL instructions.

'avx512vl'
AVX512VL instructions.

'avx512bw'
AVX512BW instructions.

'avx512dq'
AVX512DQ instructions.

'avx512cd'
AVX512CD instructions.

'avx512vbmi'
AVX512VBMI instructions.

'avx512ifma'
AVX512IFMA instructions.

'avx512vpopcntdq'
AVX512VPOPCNTDQ instructions.

'avx512vbmi2'
AVX512VBMI2 instructions.

'gfni' GFNI instructions.

'vpclmulqdq'
VPCLMULQDQ instructions.

'avx512vnni'
AVX512VNNI instructions.

'avx512bitalg'
AVX512BITALG instructions.

'x86-64' Baseline x86-64 microarchitecture level (as defined in x86-64 psABI).

'x86-64-v2'
x86-64-v2 microarchitecture level.

'x86-64-v3'
x86-64-v3 microarchitecture level.

'x86-64-v4'
x86-64-v4 microarchitecture level.

Here is an example:

```
if (__builtin_cpu_supports ("popcnt"))
  {
     asm("popcnt %1,%0" : "=r"(count) : "rm"(n) : "cc");
  }
else
  {
     count = generic_countbits (n); //generic implementation.
  }
```

The following built-in functions are made available by -mmmx. All of them generate the machine instruction that is part of the name.

```
v8qi __builtin_ia32_paddb (v8qi, v8qi);
v4hi __builtin_ia32_paddw (v4hi, v4hi);
v2si __builtin_ia32_paddd (v2si, v2si);
v8qi __builtin_ia32_psubb (v8qi, v8qi);
v4hi __builtin_ia32_psubw (v4hi, v4hi);
v2si __builtin_ia32_psubd (v2si, v2si);
v8qi __builtin_ia32_paddsb (v8qi, v8qi);
v4hi __builtin_ia32_paddsw (v4hi, v4hi);
v8qi __builtin_ia32_psubsb (v8qi, v8qi);
v4hi __builtin_ia32_psubsw (v4hi, v4hi);
v8qi __builtin_ia32_paddusb (v8qi, v8qi);
v4hi __builtin_ia32_paddusw (v4hi, v4hi);
v8qi __builtin_ia32_psubusb (v8qi, v8qi);
v4hi __builtin_ia32_psubusw (v4hi, v4hi);
v4hi __builtin_ia32_pmullw (v4hi, v4hi);
v4hi __builtin_ia32_pmulhw (v4hi, v4hi);
di __builtin_ia32_pand (di, di);
di __builtin_ia32_pandn (di,di);
di __builtin_ia32_por (di, di);
di __builtin_ia32_pxor (di, di);
v8qi __builtin_ia32_pcmpeqb (v8qi, v8qi);
v4hi __builtin_ia32_pcmpeqw (v4hi, v4hi);
v2si __builtin_ia32_pcmpeqd (v2si, v2si);
v8qi __builtin_ia32_pcmpgtb (v8qi, v8qi);
v4hi __builtin_ia32_pcmpgtw (v4hi, v4hi);
v2si __builtin_ia32_pcmpgtd (v2si, v2si);
v8qi __builtin_ia32_punpckhbw (v8qi, v8qi);
v4hi __builtin_ia32_punpckhwd (v4hi, v4hi);
v2si __builtin_ia32_punpckhdq (v2si, v2si);
v8qi __builtin_ia32_punpcklbw (v8qi, v8qi);
v4hi __builtin_ia32_punpcklwd (v4hi, v4hi);
v2si __builtin_ia32_punpckldq (v2si, v2si);
v8qi __builtin_ia32_packsswb (v4hi, v4hi);
v4hi __builtin_ia32_packssdw (v2si, v2si);
v8qi __builtin_ia32_packuswb (v4hi, v4hi);
```

```
v4hi __builtin_ia32_psllw (v4hi, v4hi);
v2si __builtin_ia32_pslld (v2si, v2si);
v1di __builtin_ia32_psllq (v1di, v1di);
v4hi __builtin_ia32_psrlw (v4hi, v4hi);
v2si __builtin_ia32_psrld (v2si, v2si);
v1di __builtin_ia32_psrlq (v1di, v1di);
v4hi __builtin_ia32_psraw (v4hi, v4hi);
v2si __builtin_ia32_psrad (v2si, v2si);
v4hi __builtin_ia32_psllwi (v4hi, int);
v2si __builtin_ia32_pslldi (v2si, int);
v1di __builtin_ia32_psllqi (v1di, int);
v4hi __builtin_ia32_psrlwi (v4hi, int);
v2si __builtin_ia32_psrldi (v2si, int);
v1di __builtin_ia32_psrlqi (v1di, int);
v4hi __builtin_ia32_psrawi (v4hi, int);
v2si __builtin_ia32_psradi (v2si, int);
```

The following built-in functions are made available either with `-msse`, or with `-m3dnowa`. All of them generate the machine instruction that is part of the name.

```
v4hi __builtin_ia32_pmulhuw (v4hi, v4hi);
v8qi __builtin_ia32_pavgb (v8qi, v8qi);
v4hi __builtin_ia32_pavgw (v4hi, v4hi);
v1di __builtin_ia32_psadbw (v8qi, v8qi);
v8qi __builtin_ia32_pmaxub (v8qi, v8qi);
v4hi __builtin_ia32_pmaxsw (v4hi, v4hi);
v8qi __builtin_ia32_pminub (v8qi, v8qi);
v4hi __builtin_ia32_pminsw (v4hi, v4hi);
int __builtin_ia32_pmovmskb (v8qi);
void __builtin_ia32_maskmovq (v8qi, v8qi, char *);
void __builtin_ia32_movntq (di *, di);
void __builtin_ia32_sfence (void);
```

The following built-in functions are available when `-msse` is used. All of them generate the machine instruction that is part of the name.

```
int __builtin_ia32_comieq (v4sf, v4sf);
int __builtin_ia32_comineq (v4sf, v4sf);
int __builtin_ia32_comilt (v4sf, v4sf);
int __builtin_ia32_comile (v4sf, v4sf);
int __builtin_ia32_comigt (v4sf, v4sf);
int __builtin_ia32_comige (v4sf, v4sf);
int __builtin_ia32_ucomieq (v4sf, v4sf);
int __builtin_ia32_ucomineq (v4sf, v4sf);
int __builtin_ia32_ucomilt (v4sf, v4sf);
int __builtin_ia32_ucomile (v4sf, v4sf);
int __builtin_ia32_ucomigt (v4sf, v4sf);
int __builtin_ia32_ucomige (v4sf, v4sf);
v4sf __builtin_ia32_addps (v4sf, v4sf);
v4sf __builtin_ia32_subps (v4sf, v4sf);
v4sf __builtin_ia32_mulps (v4sf, v4sf);
v4sf __builtin_ia32_divps (v4sf, v4sf);
v4sf __builtin_ia32_addss (v4sf, v4sf);
v4sf __builtin_ia32_subss (v4sf, v4sf);
v4sf __builtin_ia32_mulss (v4sf, v4sf);
v4sf __builtin_ia32_divss (v4sf, v4sf);
v4sf __builtin_ia32_cmpeqps (v4sf, v4sf);
v4sf __builtin_ia32_cmpltps (v4sf, v4sf);
v4sf __builtin_ia32_cmpleps (v4sf, v4sf);
```

```
v4sf __builtin_ia32_cmpgtps (v4sf, v4sf);
v4sf __builtin_ia32_cmpgeps (v4sf, v4sf);
v4sf __builtin_ia32_cmpunordps (v4sf, v4sf);
v4sf __builtin_ia32_cmpneqps (v4sf, v4sf);
v4sf __builtin_ia32_cmpnltps (v4sf, v4sf);
v4sf __builtin_ia32_cmpnleps (v4sf, v4sf);
v4sf __builtin_ia32_cmpngtps (v4sf, v4sf);
v4sf __builtin_ia32_cmpngeps (v4sf, v4sf);
v4sf __builtin_ia32_cmpordps (v4sf, v4sf);
v4sf __builtin_ia32_cmpeqss (v4sf, v4sf);
v4sf __builtin_ia32_cmpltss (v4sf, v4sf);
v4sf __builtin_ia32_cmpless (v4sf, v4sf);
v4sf __builtin_ia32_cmpunordss (v4sf, v4sf);
v4sf __builtin_ia32_cmpneqss (v4sf, v4sf);
v4sf __builtin_ia32_cmpnltss (v4sf, v4sf);
v4sf __builtin_ia32_cmpnless (v4sf, v4sf);
v4sf __builtin_ia32_cmpordss (v4sf, v4sf);
v4sf __builtin_ia32_maxps (v4sf, v4sf);
v4sf __builtin_ia32_maxss (v4sf, v4sf);
v4sf __builtin_ia32_minps (v4sf, v4sf);
v4sf __builtin_ia32_minss (v4sf, v4sf);
v4sf __builtin_ia32_andps (v4sf, v4sf);
v4sf __builtin_ia32_andnps (v4sf, v4sf);
v4sf __builtin_ia32_orps (v4sf, v4sf);
v4sf __builtin_ia32_xorps (v4sf, v4sf);
v4sf __builtin_ia32_movss (v4sf, v4sf);
v4sf __builtin_ia32_movhlps (v4sf, v4sf);
v4sf __builtin_ia32_movlhps (v4sf, v4sf);
v4sf __builtin_ia32_unpckhps (v4sf, v4sf);
v4sf __builtin_ia32_unpcklps (v4sf, v4sf);
v4sf __builtin_ia32_cvtpi2ps (v4sf, v2si);
v4sf __builtin_ia32_cvtsi2ss (v4sf, int);
v2si __builtin_ia32_cvtps2pi (v4sf);
int __builtin_ia32_cvtss2si (v4sf);
v2si __builtin_ia32_cvttps2pi (v4sf);
int __builtin_ia32_cvttss2si (v4sf);
v4sf __builtin_ia32_rcpps (v4sf);
v4sf __builtin_ia32_rsqrtps (v4sf);
v4sf __builtin_ia32_sqrtps (v4sf);
v4sf __builtin_ia32_rcpss (v4sf);
v4sf __builtin_ia32_rsqrtss (v4sf);
v4sf __builtin_ia32_sqrtss (v4sf);
v4sf __builtin_ia32_shufps (v4sf, v4sf, int);
void __builtin_ia32_movntps (float *, v4sf);
int __builtin_ia32_movmskps (v4sf);
```

The following built-in functions are available when `-msse` is used.

`v4sf __builtin_ia32_loadups (float *)` [Built-in Function]

Generates the `movups` machine instruction as a load from memory.

`void __builtin_ia32_storeups (float *, v4sf)` [Built-in Function]

Generates the `movups` machine instruction as a store to memory.

`v4sf __builtin_ia32_loadss (float *)` [Built-in Function]

Generates the `movss` machine instruction as a load from memory.

`v4sf __builtin_ia32_loadhps (v4sf, const v2sf *)` [Built-in Function]

Generates the `movhps` machine instruction as a load from memory.

v4sf __builtin_ia32_loadlps (v4sf, const v2sf *) [Built-in Function]
    Generates the movlps machine instruction as a load from memory

void __builtin_ia32_storehps (v2sf *, v4sf) [Built-in Function]
    Generates the movhps machine instruction as a store to memory.

void __builtin_ia32_storelps (v2sf *, v4sf) [Built-in Function]
    Generates the movlps machine instruction as a store to memory.

The following built-in functions are available when -msse2 is used. All of them generate the machine instruction that is part of the name.

```
int __builtin_ia32_comisdeq (v2df, v2df);
int __builtin_ia32_comisdlt (v2df, v2df);
int __builtin_ia32_comisdle (v2df, v2df);
int __builtin_ia32_comisdgt (v2df, v2df);
int __builtin_ia32_comisdge (v2df, v2df);
int __builtin_ia32_comisdneq (v2df, v2df);
int __builtin_ia32_ucomisdeq (v2df, v2df);
int __builtin_ia32_ucomisdlt (v2df, v2df);
int __builtin_ia32_ucomisdle (v2df, v2df);
int __builtin_ia32_ucomisdgt (v2df, v2df);
int __builtin_ia32_ucomisdge (v2df, v2df);
int __builtin_ia32_ucomisdneq (v2df, v2df);
v2df __builtin_ia32_cmpeqpd (v2df, v2df);
v2df __builtin_ia32_cmpltpd (v2df, v2df);
v2df __builtin_ia32_cmplepd (v2df, v2df);
v2df __builtin_ia32_cmpgtpd (v2df, v2df);
v2df __builtin_ia32_cmpgepd (v2df, v2df);
v2df __builtin_ia32_cmpunordpd (v2df, v2df);
v2df __builtin_ia32_cmpneqpd (v2df, v2df);
v2df __builtin_ia32_cmpnltpd (v2df, v2df);
v2df __builtin_ia32_cmpnlepd (v2df, v2df);
v2df __builtin_ia32_cmpngtpd (v2df, v2df);
v2df __builtin_ia32_cmpngepd (v2df, v2df);
v2df __builtin_ia32_cmpordpd (v2df, v2df);
v2df __builtin_ia32_cmpeqsd (v2df, v2df);
v2df __builtin_ia32_cmpltsd (v2df, v2df);
v2df __builtin_ia32_cmplesd (v2df, v2df);
v2df __builtin_ia32_cmpunordsd (v2df, v2df);
v2df __builtin_ia32_cmpneqsd (v2df, v2df);
v2df __builtin_ia32_cmpnltsd (v2df, v2df);
v2df __builtin_ia32_cmpnlesd (v2df, v2df);
v2df __builtin_ia32_cmpordsd (v2df, v2df);
v2di __builtin_ia32_paddq (v2di, v2di);
v2di __builtin_ia32_psubq (v2di, v2di);
v2df __builtin_ia32_addpd (v2df, v2df);
v2df __builtin_ia32_subpd (v2df, v2df);
v2df __builtin_ia32_mulpd (v2df, v2df);
v2df __builtin_ia32_divpd (v2df, v2df);
v2df __builtin_ia32_addsd (v2df, v2df);
v2df __builtin_ia32_subsd (v2df, v2df);
v2df __builtin_ia32_mulsd (v2df, v2df);
v2df __builtin_ia32_divsd (v2df, v2df);
v2df __builtin_ia32_minpd (v2df, v2df);
v2df __builtin_ia32_maxpd (v2df, v2df);
v2df __builtin_ia32_minsd (v2df, v2df);
v2df __builtin_ia32_maxsd (v2df, v2df);
```

```
v2df __builtin_ia32_andpd (v2df, v2df);
v2df __builtin_ia32_andnpd (v2df, v2df);
v2df __builtin_ia32_orpd (v2df, v2df);
v2df __builtin_ia32_xorpd (v2df, v2df);
v2df __builtin_ia32_movsd (v2df, v2df);
v2df __builtin_ia32_unpckhpd (v2df, v2df);
v2df __builtin_ia32_unpcklpd (v2df, v2df);
v16qi __builtin_ia32_paddb128 (v16qi, v16qi);
v8hi __builtin_ia32_paddw128 (v8hi, v8hi);
v4si __builtin_ia32_paddd128 (v4si, v4si);
v2di __builtin_ia32_paddq128 (v2di, v2di);
v16qi __builtin_ia32_psubb128 (v16qi, v16qi);
v8hi __builtin_ia32_psubw128 (v8hi, v8hi);
v4si __builtin_ia32_psubd128 (v4si, v4si);
v2di __builtin_ia32_psubq128 (v2di, v2di);
v8hi __builtin_ia32_pmullw128 (v8hi, v8hi);
v8hi __builtin_ia32_pmulhw128 (v8hi, v8hi);
v2di __builtin_ia32_pand128 (v2di, v2di);
v2di __builtin_ia32_pandn128 (v2di, v2di);
v2di __builtin_ia32_por128 (v2di, v2di);
v2di __builtin_ia32_pxor128 (v2di, v2di);
v16qi __builtin_ia32_pavgb128 (v16qi, v16qi);
v8hi __builtin_ia32_pavgw128 (v8hi, v8hi);
v16qi __builtin_ia32_pcmpeqb128 (v16qi, v16qi);
v8hi __builtin_ia32_pcmpeqw128 (v8hi, v8hi);
v4si __builtin_ia32_pcmpeqd128 (v4si, v4si);
v16qi __builtin_ia32_pcmpgtb128 (v16qi, v16qi);
v8hi __builtin_ia32_pcmpgtw128 (v8hi, v8hi);
v4si __builtin_ia32_pcmpgtd128 (v4si, v4si);
v16qi __builtin_ia32_pmaxub128 (v16qi, v16qi);
v8hi __builtin_ia32_pmaxsw128 (v8hi, v8hi);
v16qi __builtin_ia32_pminub128 (v16qi, v16qi);
v8hi __builtin_ia32_pminsw128 (v8hi, v8hi);
v16qi __builtin_ia32_punpckhbw128 (v16qi, v16qi);
v8hi __builtin_ia32_punpckhwd128 (v8hi, v8hi);
v4si __builtin_ia32_punpckhdq128 (v4si, v4si);
v2di __builtin_ia32_punpckhqdq128 (v2di, v2di);
v16qi __builtin_ia32_punpcklbw128 (v16qi, v16qi);
v8hi __builtin_ia32_punpcklwd128 (v8hi, v8hi);
v4si __builtin_ia32_punpckldq128 (v4si, v4si);
v2di __builtin_ia32_punpcklqdq128 (v2di, v2di);
v16qi __builtin_ia32_packsswb128 (v8hi, v8hi);
v8hi __builtin_ia32_packssdw128 (v4si, v4si);
v16qi __builtin_ia32_packuswb128 (v8hi, v8hi);
v8hi __builtin_ia32_pmulhuw128 (v8hi, v8hi);
void __builtin_ia32_maskmovdqu (v16qi, v16qi);
v2df __builtin_ia32_loadupd (double *);
void __builtin_ia32_storeupd (double *, v2df);
v2df __builtin_ia32_loadhpd (v2df, double const *);
v2df __builtin_ia32_loadlpd (v2df, double const *);
int __builtin_ia32_movmskpd (v2df);
int __builtin_ia32_pmovmskb128 (v16qi);
void __builtin_ia32_movnti (int *, int);
void __builtin_ia32_movnti64 (long long int *, long long int);
void __builtin_ia32_movntpd (double *, v2df);
void __builtin_ia32_movntdq (v2df *, v2df);
v4si __builtin_ia32_pshufd (v4si, int);
v8hi __builtin_ia32_pshuflw (v8hi, int);
```

```
v8hi __builtin_ia32_pshufhw (v8hi, int);
v2di __builtin_ia32_psadbw128 (v16qi, v16qi);
v2df __builtin_ia32_sqrtpd (v2df);
v2df __builtin_ia32_sqrtsd (v2df);
v2df __builtin_ia32_shufpd (v2df, v2df, int);
v2df __builtin_ia32_cvtdq2pd (v4si);
v4sf __builtin_ia32_cvtdq2ps (v4si);
v4si __builtin_ia32_cvtpd2dq (v2df);
v2si __builtin_ia32_cvtpd2pi (v2df);
v4sf __builtin_ia32_cvtpd2ps (v2df);
v4si __builtin_ia32_cvttpd2dq (v2df);
v2si __builtin_ia32_cvttpd2pi (v2df);
v2df __builtin_ia32_cvtpi2pd (v2si);
int __builtin_ia32_cvtsd2si (v2df);
int __builtin_ia32_cvttsd2si (v2df);
long long __builtin_ia32_cvtsd2si64 (v2df);
long long __builtin_ia32_cvttsd2si64 (v2df);
v4si __builtin_ia32_cvtps2dq (v4sf);
v2df __builtin_ia32_cvtps2pd (v4sf);
v4si __builtin_ia32_cvttps2dq (v4sf);
v2df __builtin_ia32_cvtsi2sd (v2df, int);
v2df __builtin_ia32_cvtsi642sd (v2df, long long);
v4sf __builtin_ia32_cvtsd2ss (v4sf, v2df);
v2df __builtin_ia32_cvtss2sd (v2df, v4sf);
void __builtin_ia32_clflush (const void *);
void __builtin_ia32_lfence (void);
void __builtin_ia32_mfence (void);
v16qi __builtin_ia32_loaddqu (const char *);
void __builtin_ia32_storedqu (char *, v16qi);
v1di __builtin_ia32_pmuludq (v2si, v2si);
v2di __builtin_ia32_pmuludq128 (v4si, v4si);
v8hi __builtin_ia32_psllw128 (v8hi, v8hi);
v4si __builtin_ia32_pslld128 (v4si, v4si);
v2di __builtin_ia32_psllq128 (v2di, v2di);
v8hi __builtin_ia32_psrlw128 (v8hi, v8hi);
v4si __builtin_ia32_psrld128 (v4si, v4si);
v2di __builtin_ia32_psrlq128 (v2di, v2di);
v8hi __builtin_ia32_psraw128 (v8hi, v8hi);
v4si __builtin_ia32_psrad128 (v4si, v4si);
v2di __builtin_ia32_pslldqi128 (v2di, int);
v8hi __builtin_ia32_psllwi128 (v8hi, int);
v4si __builtin_ia32_pslldi128 (v4si, int);
v2di __builtin_ia32_psllqi128 (v2di, int);
v2di __builtin_ia32_psrldqi128 (v2di, int);
v8hi __builtin_ia32_psrlwi128 (v8hi, int);
v4si __builtin_ia32_psrldi128 (v4si, int);
v2di __builtin_ia32_psrlqi128 (v2di, int);
v8hi __builtin_ia32_psrawi128 (v8hi, int);
v4si __builtin_ia32_psradi128 (v4si, int);
v4si __builtin_ia32_pmaddwd128 (v8hi, v8hi);
v2di __builtin_ia32_movq128 (v2di);
```

The following built-in functions are available when `-msse3` is used. All of them generate the machine instruction that is part of the name.

```
v2df __builtin_ia32_addsubpd (v2df, v2df);
v4sf __builtin_ia32_addsubps (v4sf, v4sf);
v2df __builtin_ia32_haddpd (v2df, v2df);
v4sf __builtin_ia32_haddps (v4sf, v4sf);
```

```
v2df __builtin_ia32_hsubpd (v2df, v2df);
v4sf __builtin_ia32_hsubps (v4sf, v4sf);
v16qi __builtin_ia32_lddqu (char const *);
void __builtin_ia32_monitor (void *, unsigned int, unsigned int);
v4sf __builtin_ia32_movshdup (v4sf);
v4sf __builtin_ia32_movsldup (v4sf);
void __builtin_ia32_mwait (unsigned int, unsigned int);
```

The following built-in functions are available when `-mssse3` is used. All of them generate the machine instruction that is part of the name.

```
v2si __builtin_ia32_phaddd (v2si, v2si);
v4hi __builtin_ia32_phaddw (v4hi, v4hi);
v4hi __builtin_ia32_phaddsw (v4hi, v4hi);
v2si __builtin_ia32_phsubd (v2si, v2si);
v4hi __builtin_ia32_phsubw (v4hi, v4hi);
v4hi __builtin_ia32_phsubsw (v4hi, v4hi);
v4hi __builtin_ia32_pmaddubsw (v8qi, v8qi);
v4hi __builtin_ia32_pmulhrsw (v4hi, v4hi);
v8qi __builtin_ia32_pshufb (v8qi, v8qi);
v8qi __builtin_ia32_psignb (v8qi, v8qi);
v2si __builtin_ia32_psignd (v2si, v2si);
v4hi __builtin_ia32_psignw (v4hi, v4hi);
v1di __builtin_ia32_palignr (v1di, v1di, int);
v8qi __builtin_ia32_pabsb (v8qi);
v2si __builtin_ia32_pabsd (v2si);
v4hi __builtin_ia32_pabsw (v4hi);
```

The following built-in functions are available when `-mssse3` is used. All of them generate the machine instruction that is part of the name.

```
v4si __builtin_ia32_phaddd128 (v4si, v4si);
v8hi __builtin_ia32_phaddw128 (v8hi, v8hi);
v8hi __builtin_ia32_phaddsw128 (v8hi, v8hi);
v4si __builtin_ia32_phsubd128 (v4si, v4si);
v8hi __builtin_ia32_phsubw128 (v8hi, v8hi);
v8hi __builtin_ia32_phsubsw128 (v8hi, v8hi);
v8hi __builtin_ia32_pmaddubsw128 (v16qi, v16qi);
v8hi __builtin_ia32_pmulhrsw128 (v8hi, v8hi);
v16qi __builtin_ia32_pshufb128 (v16qi, v16qi);
v16qi __builtin_ia32_psignb128 (v16qi, v16qi);
v4si __builtin_ia32_psignd128 (v4si, v4si);
v8hi __builtin_ia32_psignw128 (v8hi, v8hi);
v2di __builtin_ia32_palignr128 (v2di, v2di, int);
v16qi __builtin_ia32_pabsb128 (v16qi);
v4si __builtin_ia32_pabsd128 (v4si);
v8hi __builtin_ia32_pabsw128 (v8hi);
```

The following built-in functions are available when `-msse4.1` is used. All of them generate the machine instruction that is part of the name.

```
v2df __builtin_ia32_blendpd (v2df, v2df, const int);
v4sf __builtin_ia32_blendps (v4sf, v4sf, const int);
v2df __builtin_ia32_blendvpd (v2df, v2df, v2df);
v4sf __builtin_ia32_blendvps (v4sf, v4sf, v4sf);
v2df __builtin_ia32_dppd (v2df, v2df, const int);
v4sf __builtin_ia32_dpps (v4sf, v4sf, const int);
v4sf __builtin_ia32_insertps128 (v4sf, v4sf, const int);
v2di __builtin_ia32_movntdqa (v2di *);
v16qi __builtin_ia32_mpsadbw128 (v16qi, v16qi, const int);
v8hi __builtin_ia32_packusdw128 (v4si, v4si);
```

```
v16qi __builtin_ia32_pblendvb128 (v16qi, v16qi, v16qi);
v8hi __builtin_ia32_pblendw128 (v8hi, v8hi, const int);
v2di __builtin_ia32_pcmpeqq (v2di, v2di);
v8hi __builtin_ia32_phminposuw128 (v8hi);
v16qi __builtin_ia32_pmaxsb128 (v16qi, v16qi);
v4si __builtin_ia32_pmaxsd128 (v4si, v4si);
v4si __builtin_ia32_pmaxud128 (v4si, v4si);
v8hi __builtin_ia32_pmaxuw128 (v8hi, v8hi);
v16qi __builtin_ia32_pminsb128 (v16qi, v16qi);
v4si __builtin_ia32_pminsd128 (v4si, v4si);
v4si __builtin_ia32_pminud128 (v4si, v4si);
v8hi __builtin_ia32_pminuw128 (v8hi, v8hi);
v4si __builtin_ia32_pmovsxbd128 (v16qi);
v2di __builtin_ia32_pmovsxbq128 (v16qi);
v8hi __builtin_ia32_pmovsxbw128 (v16qi);
v2di __builtin_ia32_pmovsxdq128 (v4si);
v4si __builtin_ia32_pmovsxwd128 (v8hi);
v2di __builtin_ia32_pmovsxwq128 (v8hi);
v4si __builtin_ia32_pmovzxbd128 (v16qi);
v2di __builtin_ia32_pmovzxbq128 (v16qi);
v8hi __builtin_ia32_pmovzxbw128 (v16qi);
v2di __builtin_ia32_pmovzxdq128 (v4si);
v4si __builtin_ia32_pmovzxwd128 (v8hi);
v2di __builtin_ia32_pmovzxwq128 (v8hi);
v2di __builtin_ia32_pmuldq128 (v4si, v4si);
v4si __builtin_ia32_pmulld128 (v4si, v4si);
int __builtin_ia32_ptestc128 (v2di, v2di);
int __builtin_ia32_ptestnzc128 (v2di, v2di);
int __builtin_ia32_ptestz128 (v2di, v2di);
v2df __builtin_ia32_roundpd (v2df, const int);
v4sf __builtin_ia32_roundps (v4sf, const int);
v2df __builtin_ia32_roundsd (v2df, v2df, const int);
v4sf __builtin_ia32_roundss (v4sf, v4sf, const int);
```

The following built-in functions are available when `-msse4.1` is used.

`v4sf __builtin_ia32_vec_set_v4sf (v4sf, float, const int)` [Built-in Function]

Generates the `insertps` machine instruction.

`int __builtin_ia32_vec_ext_v16qi (v16qi, const int)` [Built-in Function]

Generates the `pextrb` machine instruction.

`v16qi __builtin_ia32_vec_set_v16qi (v16qi, int, const int)` [Built-in Function]

Generates the `pinsrb` machine instruction.

`v4si __builtin_ia32_vec_set_v4si (v4si, int, const int)` [Built-in Function]

Generates the `pinsrd` machine instruction.

`v2di __builtin_ia32_vec_set_v2di (v2di, long long, const int)` [Built-in Function]

Generates the `pinsrq` machine instruction in 64bit mode.

The following built-in functions are changed to generate new SSE4.1 instructions when `-msse4.1` is used.

`float __builtin_ia32_vec_ext_v4sf (v4sf, const int)` [Built-in Function]
Generates the `extractps` machine instruction.

`int __builtin_ia32_vec_ext_v4si (v4si, const int)` [Built-in Function]
Generates the `pextrd` machine instruction.

`long long __builtin_ia32_vec_ext_v2di (v2di, const int)` [Built-in Function]
Generates the `pextrq` machine instruction in 64bit mode.

The following built-in functions are available when `-msse4.2` is used. All of them generate the machine instruction that is part of the name.

```
v16qi __builtin_ia32_pcmpestrm128 (v16qi, int, v16qi, int, const int);
int __builtin_ia32_pcmpestri128 (v16qi, int, v16qi, int, const int);
int __builtin_ia32_pcmpestria128 (v16qi, int, v16qi, int, const int);
int __builtin_ia32_pcmpestric128 (v16qi, int, v16qi, int, const int);
int __builtin_ia32_pcmpestrio128 (v16qi, int, v16qi, int, const int);
int __builtin_ia32_pcmpestris128 (v16qi, int, v16qi, int, const int);
int __builtin_ia32_pcmpestriz128 (v16qi, int, v16qi, int, const int);
v16qi __builtin_ia32_pcmpistrm128 (v16qi, v16qi, const int);
int __builtin_ia32_pcmpistri128 (v16qi, v16qi, const int);
int __builtin_ia32_pcmpistria128 (v16qi, v16qi, const int);
int __builtin_ia32_pcmpistric128 (v16qi, v16qi, const int);
int __builtin_ia32_pcmpistrio128 (v16qi, v16qi, const int);
int __builtin_ia32_pcmpistris128 (v16qi, v16qi, const int);
int __builtin_ia32_pcmpistriz128 (v16qi, v16qi, const int);
v2di __builtin_ia32_pcmpgtq (v2di, v2di);
```

The following built-in functions are available when `-msse4.2` is used.

`unsigned int __builtin_ia32_crc32qi (unsigned int, unsigned char)` [Built-in Function]
Generates the `crc32b` machine instruction.

`unsigned int __builtin_ia32_crc32hi (unsigned int, unsigned short)` [Built-in Function]
Generates the `crc32w` machine instruction.

`unsigned int __builtin_ia32_crc32si (unsigned int, unsigned int)` [Built-in Function]
Generates the `crc32l` machine instruction.

`unsigned long long __builtin_ia32_crc32di (unsigned long long, unsigned long long)` [Built-in Function]
Generates the `crc32q` machine instruction.

The following built-in functions are changed to generate new SSE4.2 instructions when `-msse4.2` is used.

`int __builtin_popcount (unsigned int)` [Built-in Function]
Generates the `popcntl` machine instruction.

`int __builtin_popcountl (unsigned long)` [Built-in Function]
Generates the `popcntl` or `popcntq` machine instruction, depending on the size of `unsigned long`.

`int __builtin_popcountll (unsigned long long)` [Built-in Function]
Generates the `popcntq` machine instruction.

The following built-in functions are available when `-mavx` is used. All of them generate the machine instruction that is part of the name.

```
v4df __builtin_ia32_addpd256 (v4df,v4df);
v8sf __builtin_ia32_addps256 (v8sf,v8sf);
v4df __builtin_ia32_addsubpd256 (v4df,v4df);
v8sf __builtin_ia32_addsubps256 (v8sf,v8sf);
v4df __builtin_ia32_andnpd256 (v4df,v4df);
v8sf __builtin_ia32_andnps256 (v8sf,v8sf);
v4df __builtin_ia32_andpd256 (v4df,v4df);
v8sf __builtin_ia32_andps256 (v8sf,v8sf);
v4df __builtin_ia32_blendpd256 (v4df,v4df,int);
v8sf __builtin_ia32_blendps256 (v8sf,v8sf,int);
v4df __builtin_ia32_blendvpd256 (v4df,v4df,v4df);
v8sf __builtin_ia32_blendvps256 (v8sf,v8sf,v8sf);
v2df __builtin_ia32_cmppd (v2df,v2df,int);
v4df __builtin_ia32_cmppd256 (v4df,v4df,int);
v4sf __builtin_ia32_cmpps (v4sf,v4sf,int);
v8sf __builtin_ia32_cmpps256 (v8sf,v8sf,int);
v2df __builtin_ia32_cmpsd (v2df,v2df,int);
v4sf __builtin_ia32_cmpss (v4sf,v4sf,int);
v4df __builtin_ia32_cvtdq2pd256 (v4si);
v8sf __builtin_ia32_cvtdq2ps256 (v8si);
v4si __builtin_ia32_cvtpd2dq256 (v4df);
v4sf __builtin_ia32_cvtpd2ps256 (v4df);
v8si __builtin_ia32_cvtps2dq256 (v8sf);
v4df __builtin_ia32_cvtps2pd256 (v4sf);
v4si __builtin_ia32_cvttpd2dq256 (v4df);
v8si __builtin_ia32_cvttps2dq256 (v8sf);
v4df __builtin_ia32_divpd256 (v4df,v4df);
v8sf __builtin_ia32_divps256 (v8sf,v8sf);
v8sf __builtin_ia32_dpps256 (v8sf,v8sf,int);
v4df __builtin_ia32_haddpd256 (v4df,v4df);
v8sf __builtin_ia32_haddps256 (v8sf,v8sf);
v4df __builtin_ia32_hsubpd256 (v4df,v4df);
v8sf __builtin_ia32_hsubps256 (v8sf,v8sf);
v32qi __builtin_ia32_lddqu256 (pcchar);
v32qi __builtin_ia32_loaddqu256 (pcchar);
v4df __builtin_ia32_loadupd256 (pcdouble);
v8sf __builtin_ia32_loadups256 (pcfloat);
v2df __builtin_ia32_maskloadpd (pcv2df,v2df);
v4df __builtin_ia32_maskloadpd256 (pcv4df,v4df);
v4sf __builtin_ia32_maskloadps (pcv4sf,v4sf);
v8sf __builtin_ia32_maskloadps256 (pcv8sf,v8sf);
void __builtin_ia32_maskstorepd (pv2df,v2df,v2df);
void __builtin_ia32_maskstorepd256 (pv4df,v4df,v4df);
void __builtin_ia32_maskstoreps (pv4sf,v4sf,v4sf);
void __builtin_ia32_maskstoreps256 (pv8sf,v8sf,v8sf);
v4df __builtin_ia32_maxpd256 (v4df,v4df);
v8sf __builtin_ia32_maxps256 (v8sf,v8sf);
v4df __builtin_ia32_minpd256 (v4df,v4df);
v8sf __builtin_ia32_minps256 (v8sf,v8sf);
v4df __builtin_ia32_movddup256 (v4df);
int __builtin_ia32_movmskpd256 (v4df);
int __builtin_ia32_movmskps256 (v8sf);
v8sf __builtin_ia32_movshdup256 (v8sf);
```

```
v8sf __builtin_ia32_movsldup256 (v8sf);
v4df __builtin_ia32_mulpd256 (v4df,v4df);
v8sf __builtin_ia32_mulps256 (v8sf,v8sf);
v4df __builtin_ia32_orpd256 (v4df,v4df);
v8sf __builtin_ia32_orps256 (v8sf,v8sf);
v2df __builtin_ia32_pd_pd256 (v4df);
v4df __builtin_ia32_pd256_pd (v2df);
v4sf __builtin_ia32_ps_ps256 (v8sf);
v8sf __builtin_ia32_ps256_ps (v4sf);
int __builtin_ia32_ptestc256 (v4di,v4di,ptest);
int __builtin_ia32_ptestnzc256 (v4di,v4di,ptest);
int __builtin_ia32_ptestz256 (v4di,v4di,ptest);
v8sf __builtin_ia32_rcpps256 (v8sf);
v4df __builtin_ia32_roundpd256 (v4df,int);
v8sf __builtin_ia32_roundps256 (v8sf,int);
v8sf __builtin_ia32_rsqrtps_nr256 (v8sf);
v8sf __builtin_ia32_rsqrtps256 (v8sf);
v4df __builtin_ia32_shufpd256 (v4df,v4df,int);
v8sf __builtin_ia32_shufps256 (v8sf,v8sf,int);
v4si __builtin_ia32_si_si256 (v8si);
v8si __builtin_ia32_si256_si (v4si);
v4df __builtin_ia32_sqrtpd256 (v4df);
v8sf __builtin_ia32_sqrtps_nr256 (v8sf);
v8sf __builtin_ia32_sqrtps256 (v8sf);
void __builtin_ia32_storedqu256 (pchar,v32qi);
void __builtin_ia32_storeupd256 (pdouble,v4df);
void __builtin_ia32_storeups256 (pfloat,v8sf);
v4df __builtin_ia32_subpd256 (v4df,v4df);
v8sf __builtin_ia32_subps256 (v8sf,v8sf);
v4df __builtin_ia32_unpckhpd256 (v4df,v4df);
v8sf __builtin_ia32_unpckhps256 (v8sf,v8sf);
v4df __builtin_ia32_unpcklpd256 (v4df,v4df);
v8sf __builtin_ia32_unpcklps256 (v8sf,v8sf);
v4df __builtin_ia32_vbroadcastf128_pd256 (pcv2df);
v8sf __builtin_ia32_vbroadcastf128_ps256 (pcv4sf);
v4df __builtin_ia32_vbroadcastsd256 (pcdouble);
v4sf __builtin_ia32_vbroadcastss (pcfloat);
v8sf __builtin_ia32_vbroadcastss256 (pcfloat);
v2df __builtin_ia32_vextractf128_pd256 (v4df,int);
v4sf __builtin_ia32_vextractf128_ps256 (v8sf,int);
v4si __builtin_ia32_vextractf128_si256 (v8si,int);
v4df __builtin_ia32_vinsertf128_pd256 (v4df,v2df,int);
v8sf __builtin_ia32_vinsertf128_ps256 (v8sf,v4sf,int);
v8si __builtin_ia32_vinsertf128_si256 (v8si,v4si,int);
v4df __builtin_ia32_vperm2f128_pd256 (v4df,v4df,int);
v8sf __builtin_ia32_vperm2f128_ps256 (v8sf,v8sf,int);
v8si __builtin_ia32_vperm2f128_si256 (v8si,v8si,int);
v2df __builtin_ia32_vpermil2pd (v2df,v2df,v2di,int);
v4df __builtin_ia32_vpermil2pd256 (v4df,v4df,v4di,int);
v4sf __builtin_ia32_vpermil2ps (v4sf,v4sf,v4si,int);
v8sf __builtin_ia32_vpermil2ps256 (v8sf,v8sf,v8si,int);
v2df __builtin_ia32_vpermilpd (v2df,int);
v4df __builtin_ia32_vpermilpd256 (v4df,int);
v4sf __builtin_ia32_vpermilps (v4sf,int);
v8sf __builtin_ia32_vpermilps256 (v8sf,int);
v2df __builtin_ia32_vpermilvarpd (v2df,v2di);
v4df __builtin_ia32_vpermilvarpd256 (v4df,v4di);
v4sf __builtin_ia32_vpermilvarps (v4sf,v4si);
```

```
v8sf __builtin_ia32_vpermilvarps256 (v8sf,v8si);
int __builtin_ia32_vtestcpd (v2df,v2df,ptest);
int __builtin_ia32_vtestcpd256 (v4df,v4df,ptest);
int __builtin_ia32_vtestcps (v4sf,v4sf,ptest);
int __builtin_ia32_vtestcps256 (v8sf,v8sf,ptest);
int __builtin_ia32_vtestnzcpd (v2df,v2df,ptest);
int __builtin_ia32_vtestnzcpd256 (v4df,v4df,ptest);
int __builtin_ia32_vtestnzcps (v4sf,v4sf,ptest);
int __builtin_ia32_vtestnzcps256 (v8sf,v8sf,ptest);
int __builtin_ia32_vtestzpd (v2df,v2df,ptest);
int __builtin_ia32_vtestzpd256 (v4df,v4df,ptest);
int __builtin_ia32_vtestzps (v4sf,v4sf,ptest);
int __builtin_ia32_vtestzps256 (v8sf,v8sf,ptest);
void __builtin_ia32_vzeroall (void);
void __builtin_ia32_vzeroupper (void);
v4df __builtin_ia32_xorpd256 (v4df,v4df);
v8sf __builtin_ia32_xorps256 (v8sf,v8sf);
```

The following built-in functions are available when `-mavx2` is used. All of them generate the machine instruction that is part of the name.

```
v32qi __builtin_ia32_mpsadbw256 (v32qi,v32qi,int);
v32qi __builtin_ia32_pabsb256 (v32qi);
v16hi __builtin_ia32_pabsw256 (v16hi);
v8si __builtin_ia32_pabsd256 (v8si);
v16hi __builtin_ia32_packssdw256 (v8si,v8si);
v32qi __builtin_ia32_packsswb256 (v16hi,v16hi);
v16hi __builtin_ia32_packusdw256 (v8si,v8si);
v32qi __builtin_ia32_packuswb256 (v16hi,v16hi);
v32qi __builtin_ia32_paddb256 (v32qi,v32qi);
v16hi __builtin_ia32_paddw256 (v16hi,v16hi);
v8si __builtin_ia32_paddd256 (v8si,v8si);
v4di __builtin_ia32_paddq256 (v4di,v4di);
v32qi __builtin_ia32_paddsb256 (v32qi,v32qi);
v16hi __builtin_ia32_paddsw256 (v16hi,v16hi);
v32qi __builtin_ia32_paddusb256 (v32qi,v32qi);
v16hi __builtin_ia32_paddusw256 (v16hi,v16hi);
v4di __builtin_ia32_palignr256 (v4di,v4di,int);
v4di __builtin_ia32_andsi256 (v4di,v4di);
v4di __builtin_ia32_andnotsi256 (v4di,v4di);
v32qi __builtin_ia32_pavgb256 (v32qi,v32qi);
v16hi __builtin_ia32_pavgw256 (v16hi,v16hi);
v32qi __builtin_ia32_pblendvb256 (v32qi,v32qi,v32qi);
v16hi __builtin_ia32_pblendw256 (v16hi,v16hi,int);
v32qi __builtin_ia32_pcmpeqb256 (v32qi,v32qi);
v16hi __builtin_ia32_pcmpeqw256 (v16hi,v16hi);
v8si __builtin_ia32_pcmpeqd256 (c8si,v8si);
v4di __builtin_ia32_pcmpeqq256 (v4di,v4di);
v32qi __builtin_ia32_pcmpgtb256 (v32qi,v32qi);
v16hi __builtin_ia32_pcmpgtw256 (16hi,v16hi);
v8si __builtin_ia32_pcmpgtd256 (v8si,v8si);
v4di __builtin_ia32_pcmpgtq256 (v4di,v4di);
v16hi __builtin_ia32_phaddw256 (v16hi,v16hi);
v8si __builtin_ia32_phaddd256 (v8si,v8si);
v16hi __builtin_ia32_phaddsw256 (v16hi,v16hi);
v16hi __builtin_ia32_phsubw256 (v16hi,v16hi);
v8si __builtin_ia32_phsubd256 (v8si,v8si);
v16hi __builtin_ia32_phsubsw256 (v16hi,v16hi);
v32qi __builtin_ia32_pmaddubsw256 (v32qi,v32qi);
```

```
v16hi __builtin_ia32_pmaddwd256 (v16hi,v16hi);
v32qi __builtin_ia32_pmaxsb256 (v32qi,v32qi);
v16hi __builtin_ia32_pmaxsw256 (v16hi,v16hi);
v8si __builtin_ia32_pmaxsd256 (v8si,v8si);
v32qi __builtin_ia32_pmaxub256 (v32qi,v32qi);
v16hi __builtin_ia32_pmaxuw256 (v16hi,v16hi);
v8si __builtin_ia32_pmaxud256 (v8si,v8si);
v32qi __builtin_ia32_pminsb256 (v32qi,v32qi);
v16hi __builtin_ia32_pminsw256 (v16hi,v16hi);
v8si __builtin_ia32_pminsd256 (v8si,v8si);
v32qi __builtin_ia32_pminub256 (v32qi,v32qi);
v16hi __builtin_ia32_pminuw256 (v16hi,v16hi);
v8si __builtin_ia32_pminud256 (v8si,v8si);
int __builtin_ia32_pmovmskb256 (v32qi);
v16hi __builtin_ia32_pmovsxbw256 (v16qi);
v8si __builtin_ia32_pmovsxbd256 (v16qi);
v4di __builtin_ia32_pmovsxbq256 (v16qi);
v8si __builtin_ia32_pmovsxwd256 (v8hi);
v4di __builtin_ia32_pmovsxwq256 (v8hi);
v4di __builtin_ia32_pmovsxdq256 (v4si);
v16hi __builtin_ia32_pmovzxbw256 (v16qi);
v8si __builtin_ia32_pmovzxbd256 (v16qi);
v4di __builtin_ia32_pmovzxbq256 (v16qi);
v8si __builtin_ia32_pmovzxwd256 (v8hi);
v4di __builtin_ia32_pmovzxwq256 (v8hi);
v4di __builtin_ia32_pmovzxdq256 (v4si);
v4di __builtin_ia32_pmuldq256 (v8si,v8si);
v16hi __builtin_ia32_pmulhrsw256 (v16hi, v16hi);
v16hi __builtin_ia32_pmulhuw256 (v16hi,v16hi);
v16hi __builtin_ia32_pmulhw256 (v16hi,v16hi);
v16hi __builtin_ia32_pmullw256 (v16hi,v16hi);
v8si __builtin_ia32_pmulld256 (v8si,v8si);
v4di __builtin_ia32_pmuludq256 (v8si,v8si);
v4di __builtin_ia32_por256 (v4di,v4di);
v16hi __builtin_ia32_psadbw256 (v32qi,v32qi);
v32qi __builtin_ia32_pshufb256 (v32qi,v32qi);
v8si __builtin_ia32_pshufd256 (v8si,int);
v16hi __builtin_ia32_pshufhw256 (v16hi,int);
v16hi __builtin_ia32_pshuflw256 (v16hi,int);
v32qi __builtin_ia32_psignb256 (v32qi,v32qi);
v16hi __builtin_ia32_psignw256 (v16hi,v16hi);
v8si __builtin_ia32_psignd256 (v8si,v8si);
v4di __builtin_ia32_pslldqi256 (v4di,int);
v16hi __builtin_ia32_psllwi256 (16hi,int);
v16hi __builtin_ia32_psllw256(v16hi,v8hi);
v8si __builtin_ia32_pslldi256 (v8si,int);
v8si __builtin_ia32_pslld256(v8si,v4si);
v4di __builtin_ia32_psllqi256 (v4di,int);
v4di __builtin_ia32_psllq256(v4di,v2di);
v16hi __builtin_ia32_psrawi256 (v16hi,int);
v16hi __builtin_ia32_psraw256 (v16hi,v8hi);
v8si __builtin_ia32_psradi256 (v8si,int);
v8si __builtin_ia32_psrad256 (v8si,v4si);
v4di __builtin_ia32_psrldqi256 (v4di, int);
v16hi __builtin_ia32_psrlwi256 (v16hi,int);
v16hi __builtin_ia32_psrlw256 (v16hi,v8hi);
v8si __builtin_ia32_psrldi256 (v8si,int);
v8si __builtin_ia32_psrld256 (v8si,v4si);
```

```
v4di __builtin_ia32_psrlqi256 (v4di,int);
v4di __builtin_ia32_psrlq256(v4di,v2di);
v32qi __builtin_ia32_psubb256 (v32qi,v32qi);
v32hi __builtin_ia32_psubw256 (v16hi,v16hi);
v8si __builtin_ia32_psubd256 (v8si,v8si);
v4di __builtin_ia32_psubq256 (v4di,v4di);
v32qi __builtin_ia32_psubsb256 (v32qi,v32qi);
v16hi __builtin_ia32_psubsw256 (v16hi,v16hi);
v32qi __builtin_ia32_psubusb256 (v32qi,v32qi);
v16hi __builtin_ia32_psubusw256 (v16hi,v16hi);
v32qi __builtin_ia32_punpckhbw256 (v32qi,v32qi);
v16hi __builtin_ia32_punpckhwd256 (v16hi,v16hi);
v8si __builtin_ia32_punpckhdq256 (v8si,v8si);
v4di __builtin_ia32_punpckhqdq256 (v4di,v4di);
v32qi __builtin_ia32_punpcklbw256 (v32qi,v32qi);
v16hi __builtin_ia32_punpcklwd256 (v16hi,v16hi);
v8si __builtin_ia32_punpckldq256 (v8si,v8si);
v4di __builtin_ia32_punpcklqdq256 (v4di,v4di);
v4di __builtin_ia32_pxor256 (v4di,v4di);
v4di __builtin_ia32_movntdqa256 (pv4di);
v4sf __builtin_ia32_vbroadcastss_ps (v4sf);
v8sf __builtin_ia32_vbroadcastss_ps256 (v4sf);
v4df __builtin_ia32_vbroadcastsd_pd256 (v2df);
v4di __builtin_ia32_vbroadcastsi256 (v2di);
v4si __builtin_ia32_pblendd128 (v4si,v4si);
v8si __builtin_ia32_pblendd256 (v8si,v8si);
v32qi __builtin_ia32_pbroadcastb256 (v16qi);
v16hi __builtin_ia32_pbroadcastw256 (v8hi);
v8si __builtin_ia32_pbroadcastd256 (v4si);
v4di __builtin_ia32_pbroadcastq256 (v2di);
v16qi __builtin_ia32_pbroadcastb128 (v16qi);
v8hi __builtin_ia32_pbroadcastw128 (v8hi);
v4si __builtin_ia32_pbroadcastd128 (v4si);
v2di __builtin_ia32_pbroadcastq128 (v2di);
v8si __builtin_ia32_permvarsi256 (v8si,v8si);
v4df __builtin_ia32_permdf256 (v4df,int);
v8sf __builtin_ia32_permvarsf256 (v8sf,v8sf);
v4di __builtin_ia32_permdi256 (v4di,int);
v4di __builtin_ia32_permti256 (v4di,v4di,int);
v4di __builtin_ia32_extract128i256 (v4di,int);
v4di __builtin_ia32_insert128i256 (v4di,v2di,int);
v8si __builtin_ia32_maskloadd256 (pcv8si,v8si);
v4di __builtin_ia32_maskloadq256 (pcv4di,v4di);
v4si __builtin_ia32_maskloadd (pcv4si,v4si);
v2di __builtin_ia32_maskloadq (pcv2di,v2di);
void __builtin_ia32_maskstored256 (pv8si,v8si,v8si);
void __builtin_ia32_maskstoreq256 (pv4di,v4di,v4di);
void __builtin_ia32_maskstored (pv4si,v4si,v4si);
void __builtin_ia32_maskstoreq (pv2di,v2di,v2di);
v8si __builtin_ia32_psllv8si (v8si,v8si);
v4si __builtin_ia32_psllv4si (v4si,v4si);
v4di __builtin_ia32_psllv4di (v4di,v4di);
v2di __builtin_ia32_psllv2di (v2di,v2di);
v8si __builtin_ia32_psrav8si (v8si,v8si);
v4si __builtin_ia32_psrav4si (v4si,v4si);
v8si __builtin_ia32_psrlv8si (v8si,v8si);
v4si __builtin_ia32_psrlv4si (v4si,v4si);
v4di __builtin_ia32_psrlv4di (v4di,v4di);
```

```
v2di __builtin_ia32_psrlv2di (v2di,v2di);
v2df __builtin_ia32_gathersiv2df (v2df, pcdouble,v4si,v2df,int);
v4df __builtin_ia32_gathersiv4df (v4df, pcdouble,v4si,v4df,int);
v2df __builtin_ia32_gatherdiv2df (v2df, pcdouble,v2di,v2df,int);
v4df __builtin_ia32_gatherdiv4df (v4df, pcdouble,v4di,v4df,int);
v4sf __builtin_ia32_gathersiv4sf (v4sf, pcfloat,v4si,v4sf,int);
v8sf __builtin_ia32_gathersiv8sf (v8sf, pcfloat,v8si,v8sf,int);
v4sf __builtin_ia32_gatherdiv4sf (v4sf, pcfloat,v2di,v4sf,int);
v4sf __builtin_ia32_gatherdiv4sf256 (v4sf, pcfloat,v4di,v4sf,int);
v2di __builtin_ia32_gathersiv2di (v2di, pcint64,v4si,v2di,int);
v4di __builtin_ia32_gathersiv4di (v4di, pcint64,v4si,v4di,int);
v2di __builtin_ia32_gatherdiv2di (v2di, pcint64,v2di,v2di,int);
v4di __builtin_ia32_gatherdiv4di (v4di, pcint64,v4di,v4di,int);
v4si __builtin_ia32_gathersiv4si (v4si, pcint,v4si,v4si,int);
v8si __builtin_ia32_gathersiv8si (v8si, pcint,v8si,v8si,int);
v4si __builtin_ia32_gatherdiv4si (v4si, pcint,v2di,v4si,int);
v4si __builtin_ia32_gatherdiv4si256 (v4si, pcint,v4di,v4si,int);
```

The following built-in functions are available when `-maes` is used. All of them generate the machine instruction that is part of the name.

```
v2di __builtin_ia32_aesenc128 (v2di, v2di);
v2di __builtin_ia32_aesenclast128 (v2di, v2di);
v2di __builtin_ia32_aesdec128 (v2di, v2di);
v2di __builtin_ia32_aesdeclast128 (v2di, v2di);
v2di __builtin_ia32_aeskeygenassist128 (v2di, const int);
v2di __builtin_ia32_aesimc128 (v2di);
```

The following built-in function is available when `-mpclmul` is used.

`v2di __builtin_ia32_pclmulqdq128 (v2di, v2di, const int)` [Built-in Function]

Generates the `pclmulqdq` machine instruction.

The following built-in function is available when `-mfsgsbase` is used. All of them generate the machine instruction that is part of the name.

```
unsigned int __builtin_ia32_rdfsbase32 (void);
unsigned long long __builtin_ia32_rdfsbase64 (void);
unsigned int __builtin_ia32_rdgsbase32 (void);
unsigned long long __builtin_ia32_rdgsbase64 (void);
void _writefsbase_u32 (unsigned int);
void _writefsbase_u64 (unsigned long long);
void _writegsbase_u32 (unsigned int);
void _writegsbase_u64 (unsigned long long);
```

The following built-in function is available when `-mrdrnd` is used. All of them generate the machine instruction that is part of the name.

```
unsigned int __builtin_ia32_rdrand16_step (unsigned short *);
unsigned int __builtin_ia32_rdrand32_step (unsigned int *);
unsigned int __builtin_ia32_rdrand64_step (unsigned long long *);
```

The following built-in function is available when `-mptwrite` is used. All of them generate the machine instruction that is part of the name.

```
void __builtin_ia32_ptwrite32 (unsigned);
void __builtin_ia32_ptwrite64 (unsigned long long);
```

The following built-in functions are available when `-msse4a` is used. All of them generate the machine instruction that is part of the name.

```
void __builtin_ia32_movntsd (double *, v2df);
```

```
void __builtin_ia32_movntss (float *, v4sf);
v2di __builtin_ia32_extrq  (v2di, v16qi);
v2di __builtin_ia32_extrqi (v2di, const unsigned int, const unsigned int);
v2di __builtin_ia32_insertq (v2di, v2di);
v2di __builtin_ia32_insertqi (v2di, v2di, const unsigned int, const unsigned int);
```

The following built-in functions are available when `-mxop` is used.

```
v2df __builtin_ia32_vfrczpd (v2df);
v4sf __builtin_ia32_vfrczps (v4sf);
v2df __builtin_ia32_vfrczsd (v2df);
v4sf __builtin_ia32_vfrczss (v4sf);
v4df __builtin_ia32_vfrczpd256 (v4df);
v8sf __builtin_ia32_vfrczps256 (v8sf);
v2di __builtin_ia32_vpcmov (v2di, v2di, v2di);
v2di __builtin_ia32_vpcmov_v2di (v2di, v2di, v2di);
v4si __builtin_ia32_vpcmov_v4si (v4si, v4si, v4si);
v8hi __builtin_ia32_vpcmov_v8hi (v8hi, v8hi, v8hi);
v16qi __builtin_ia32_vpcmov_v16qi (v16qi, v16qi, v16qi);
v2df __builtin_ia32_vpcmov_v2df (v2df, v2df, v2df);
v4sf __builtin_ia32_vpcmov_v4sf (v4sf, v4sf, v4sf);
v4di __builtin_ia32_vpcmov_v4di256 (v4di, v4di, v4di);
v8si __builtin_ia32_vpcmov_v8si256 (v8si, v8si, v8si);
v16hi __builtin_ia32_vpcmov_v16hi256 (v16hi, v16hi, v16hi);
v32qi __builtin_ia32_vpcmov_v32qi256 (v32qi, v32qi, v32qi);
v4df __builtin_ia32_vpcmov_v4df256 (v4df, v4df, v4df);
v8sf __builtin_ia32_vpcmov_v8sf256 (v8sf, v8sf, v8sf);
v16qi __builtin_ia32_vpcomeqb (v16qi, v16qi);
v8hi __builtin_ia32_vpcomeqw (v8hi, v8hi);
v4si __builtin_ia32_vpcomeqd (v4si, v4si);
v2di __builtin_ia32_vpcomeqq (v2di, v2di);
v16qi __builtin_ia32_vpcomequb (v16qi, v16qi);
v4si __builtin_ia32_vpcomequd (v4si, v4si);
v2di __builtin_ia32_vpcomequq (v2di, v2di);
v8hi __builtin_ia32_vpcomequw (v8hi, v8hi);
v8hi __builtin_ia32_vpcomeqw (v8hi, v8hi);
v16qi __builtin_ia32_vpcomfalseb (v16qi, v16qi);
v4si __builtin_ia32_vpcomfalsed (v4si, v4si);
v2di __builtin_ia32_vpcomfalseq (v2di, v2di);
v16qi __builtin_ia32_vpcomfalseub (v16qi, v16qi);
v4si __builtin_ia32_vpcomfalseud (v4si, v4si);
v2di __builtin_ia32_vpcomfalseuq (v2di, v2di);
v8hi __builtin_ia32_vpcomfalseuw (v8hi, v8hi);
v8hi __builtin_ia32_vpcomfalsew (v8hi, v8hi);
v16qi __builtin_ia32_vpcomgeb (v16qi, v16qi);
v4si __builtin_ia32_vpcomged (v4si, v4si);
v2di __builtin_ia32_vpcomgeq (v2di, v2di);
v16qi __builtin_ia32_vpcomgeub (v16qi, v16qi);
v4si __builtin_ia32_vpcomgeud (v4si, v4si);
v2di __builtin_ia32_vpcomgeuq (v2di, v2di);
v8hi __builtin_ia32_vpcomgeuw (v8hi, v8hi);
v8hi __builtin_ia32_vpcomgew (v8hi, v8hi);
v16qi __builtin_ia32_vpcomgtb (v16qi, v16qi);
v4si __builtin_ia32_vpcomgtd (v4si, v4si);
v2di __builtin_ia32_vpcomgtq (v2di, v2di);
v16qi __builtin_ia32_vpcomgtub (v16qi, v16qi);
v4si __builtin_ia32_vpcomgtud (v4si, v4si);
v2di __builtin_ia32_vpcomgtuq (v2di, v2di);
v8hi __builtin_ia32_vpcomgtuw (v8hi, v8hi);
v8hi __builtin_ia32_vpcomgtw (v8hi, v8hi);
```

```
v16qi __builtin_ia32_vpcomleb (v16qi, v16qi);
v4si __builtin_ia32_vpcomled (v4si, v4si);
v2di __builtin_ia32_vpcomleq (v2di, v2di);
v16qi __builtin_ia32_vpcomleub (v16qi, v16qi);
v4si __builtin_ia32_vpcomleud (v4si, v4si);
v2di __builtin_ia32_vpcomleuq (v2di, v2di);
v8hi __builtin_ia32_vpcomleuw (v8hi, v8hi);
v8hi __builtin_ia32_vpcomlew (v8hi, v8hi);
v16qi __builtin_ia32_vpcomltb (v16qi, v16qi);
v4si __builtin_ia32_vpcomltd (v4si, v4si);
v2di __builtin_ia32_vpcomltq (v2di, v2di);
v16qi __builtin_ia32_vpcomltub (v16qi, v16qi);
v4si __builtin_ia32_vpcomltud (v4si, v4si);
v2di __builtin_ia32_vpcomltuq (v2di, v2di);
v8hi __builtin_ia32_vpcomltuw (v8hi, v8hi);
v8hi __builtin_ia32_vpcomltw (v8hi, v8hi);
v16qi __builtin_ia32_vpcomneb (v16qi, v16qi);
v4si __builtin_ia32_vpcomned (v4si, v4si);
v2di __builtin_ia32_vpcomneq (v2di, v2di);
v16qi __builtin_ia32_vpcomneub (v16qi, v16qi);
v4si __builtin_ia32_vpcomneud (v4si, v4si);
v2di __builtin_ia32_vpcomneuq (v2di, v2di);
v8hi __builtin_ia32_vpcomneuw (v8hi, v8hi);
v8hi __builtin_ia32_vpcomnew (v8hi, v8hi);
v16qi __builtin_ia32_vpcomtrueb (v16qi, v16qi);
v4si __builtin_ia32_vpcomtrued (v4si, v4si);
v2di __builtin_ia32_vpcomtrueq (v2di, v2di);
v16qi __builtin_ia32_vpcomtrueub (v16qi, v16qi);
v4si __builtin_ia32_vpcomtrueud (v4si, v4si);
v2di __builtin_ia32_vpcomtrueuq (v2di, v2di);
v8hi __builtin_ia32_vpcomtrueuw (v8hi, v8hi);
v8hi __builtin_ia32_vpcomtruew (v8hi, v8hi);
v4si __builtin_ia32_vphaddbd (v16qi);
v2di __builtin_ia32_vphaddbq (v16qi);
v8hi __builtin_ia32_vphaddbw (v16qi);
v2di __builtin_ia32_vphadddq (v4si);
v4si __builtin_ia32_vphaddubd (v16qi);
v2di __builtin_ia32_vphaddubq (v16qi);
v8hi __builtin_ia32_vphaddubw (v16qi);
v2di __builtin_ia32_vphaddudq (v4si);
v4si __builtin_ia32_vphadduwd (v8hi);
v2di __builtin_ia32_vphadduwq (v8hi);
v4si __builtin_ia32_vphaddwd (v8hi);
v2di __builtin_ia32_vphaddwq (v8hi);
v8hi __builtin_ia32_vphsubbw (v16qi);
v2di __builtin_ia32_vphsubdq (v4si);
v4si __builtin_ia32_vphsubwd (v8hi);
v4si __builtin_ia32_vpmacsdd (v4si, v4si, v4si);
v2di __builtin_ia32_vpmacsdqh (v4si, v4si, v2di);
v2di __builtin_ia32_vpmacsdql (v4si, v4si, v2di);
v4si __builtin_ia32_vpmacssdd (v4si, v4si, v4si);
v2di __builtin_ia32_vpmacssdqh (v4si, v4si, v2di);
v2di __builtin_ia32_vpmacssdql (v4si, v4si, v2di);
v4si __builtin_ia32_vpmacsswd (v8hi, v8hi, v4si);
v8hi __builtin_ia32_vpmacssww (v8hi, v8hi, v8hi);
v4si __builtin_ia32_vpmacswd (v8hi, v8hi, v4si);
v8hi __builtin_ia32_vpmacsww (v8hi, v8hi, v8hi);
v4si __builtin_ia32_vpmadcsswd (v8hi, v8hi, v4si);
```

```
v4si __builtin_ia32_vpmadcswd (v8hi, v8hi, v4si);
v16qi __builtin_ia32_vpperm (v16qi, v16qi, v16qi);
v16qi __builtin_ia32_vprotb (v16qi, v16qi);
v4si __builtin_ia32_vprotd (v4si, v4si);
v2di __builtin_ia32_vprotq (v2di, v2di);
v8hi __builtin_ia32_vprotw (v8hi, v8hi);
v16qi __builtin_ia32_vpshab (v16qi, v16qi);
v4si __builtin_ia32_vpshad (v4si, v4si);
v2di __builtin_ia32_vpshaq (v2di, v2di);
v8hi __builtin_ia32_vpshaw (v8hi, v8hi);
v16qi __builtin_ia32_vpshlb (v16qi, v16qi);
v4si __builtin_ia32_vpshld (v4si, v4si);
v2di __builtin_ia32_vpshlq (v2di, v2di);
v8hi __builtin_ia32_vpshlw (v8hi, v8hi);
```

The following built-in functions are available when `-mfma4` is used. All of them generate the machine instruction that is part of the name.

```
v2df __builtin_ia32_vfmaddpd (v2df, v2df, v2df);
v4sf __builtin_ia32_vfmaddps (v4sf, v4sf, v4sf);
v2df __builtin_ia32_vfmaddsd (v2df, v2df, v2df);
v4sf __builtin_ia32_vfmaddss (v4sf, v4sf, v4sf);
v2df __builtin_ia32_vfmsubpd (v2df, v2df, v2df);
v4sf __builtin_ia32_vfmsubps (v4sf, v4sf, v4sf);
v2df __builtin_ia32_vfmsubsd (v2df, v2df, v2df);
v4sf __builtin_ia32_vfmsubss (v4sf, v4sf, v4sf);
v2df __builtin_ia32_vfnmaddpd (v2df, v2df, v2df);
v4sf __builtin_ia32_vfnmaddps (v4sf, v4sf, v4sf);
v2df __builtin_ia32_vfnmaddsd (v2df, v2df, v2df);
v4sf __builtin_ia32_vfnmaddss (v4sf, v4sf, v4sf);
v2df __builtin_ia32_vfnmsubpd (v2df, v2df, v2df);
v4sf __builtin_ia32_vfnmsubps (v4sf, v4sf, v4sf);
v2df __builtin_ia32_vfnmsubsd (v2df, v2df, v2df);
v4sf __builtin_ia32_vfnmsubss (v4sf, v4sf, v4sf);
v2df __builtin_ia32_vfmaddsubpd  (v2df, v2df, v2df);
v4sf __builtin_ia32_vfmaddsubps  (v4sf, v4sf, v4sf);
v2df __builtin_ia32_vfmsubaddpd  (v2df, v2df, v2df);
v4sf __builtin_ia32_vfmsubaddps  (v4sf, v4sf, v4sf);
v4df __builtin_ia32_vfmaddpd256 (v4df, v4df, v4df);
v8sf __builtin_ia32_vfmaddps256 (v8sf, v8sf, v8sf);
v4df __builtin_ia32_vfmsubpd256 (v4df, v4df, v4df);
v8sf __builtin_ia32_vfmsubps256 (v8sf, v8sf, v8sf);
v4df __builtin_ia32_vfnmaddpd256 (v4df, v4df, v4df);
v8sf __builtin_ia32_vfnmaddps256 (v8sf, v8sf, v8sf);
v4df __builtin_ia32_vfnmsubpd256 (v4df, v4df, v4df);
v8sf __builtin_ia32_vfnmsubps256 (v8sf, v8sf, v8sf);
v4df __builtin_ia32_vfmaddsubpd256 (v4df, v4df, v4df);
v8sf __builtin_ia32_vfmaddsubps256 (v8sf, v8sf, v8sf);
v4df __builtin_ia32_vfmsubaddpd256 (v4df, v4df, v4df);
v8sf __builtin_ia32_vfmsubaddps256 (v8sf, v8sf, v8sf);
```

The following built-in functions are available when `-mlwp` is used.

```
void __builtin_ia32_llwpcb16 (void *);
void __builtin_ia32_llwpcb32 (void *);
void __builtin_ia32_llwpcb64 (void *);
void * __builtin_ia32_llwpcb16 (void);
void * __builtin_ia32_llwpcb32 (void);
void * __builtin_ia32_llwpcb64 (void);
void __builtin_ia32_lwpval16 (unsigned short, unsigned int, unsigned short);
```

```
void __builtin_ia32_lwpval32 (unsigned int, unsigned int, unsigned int);
void __builtin_ia32_lwpval64 (unsigned __int64, unsigned int, unsigned int);
unsigned char __builtin_ia32_lwpins16 (unsigned short, unsigned int, unsigned short);
unsigned char __builtin_ia32_lwpins32 (unsigned int, unsigned int, unsigned int);
unsigned char __builtin_ia32_lwpins64 (unsigned __int64, unsigned int, unsigned int);
```

The following built-in functions are available when `-mbmi` is used. All of them generate the machine instruction that is part of the name.

```
unsigned int __builtin_ia32_bextr_u32(unsigned int, unsigned int);
unsigned long long __builtin_ia32_bextr_u64 (unsigned long long, unsigned long long);
```

The following built-in functions are available when `-mbmi2` is used. All of them generate the machine instruction that is part of the name.

```
unsigned int _bzhi_u32 (unsigned int, unsigned int);
unsigned int _pdep_u32 (unsigned int, unsigned int);
unsigned int _pext_u32 (unsigned int, unsigned int);
unsigned long long _bzhi_u64 (unsigned long long, unsigned long long);
unsigned long long _pdep_u64 (unsigned long long, unsigned long long);
unsigned long long _pext_u64 (unsigned long long, unsigned long long);
```

The following built-in functions are available when `-mlzcnt` is used. All of them generate the machine instruction that is part of the name.

```
unsigned short __builtin_ia32_lzcnt_u16(unsigned short);
unsigned int __builtin_ia32_lzcnt_u32(unsigned int);
unsigned long long __builtin_ia32_lzcnt_u64 (unsigned long long);
```

The following built-in functions are available when `-mfxsr` is used. All of them generate the machine instruction that is part of the name.

```
void __builtin_ia32_fxsave (void *);
void __builtin_ia32_fxrstor (void *);
void __builtin_ia32_fxsave64 (void *);
void __builtin_ia32_fxrstor64 (void *);
```

The following built-in functions are available when `-mxsave` is used. All of them generate the machine instruction that is part of the name.

```
void __builtin_ia32_xsave (void *, long long);
void __builtin_ia32_xrstor (void *, long long);
void __builtin_ia32_xsave64 (void *, long long);
void __builtin_ia32_xrstor64 (void *, long long);
```

The following built-in functions are available when `-mxsaveopt` is used. All of them generate the machine instruction that is part of the name.

```
void __builtin_ia32_xsaveopt (void *, long long);
void __builtin_ia32_xsaveopt64 (void *, long long);
```

The following built-in functions are available when `-mtbm` is used. Both of them generate the immediate form of the bextr machine instruction.

```
unsigned int __builtin_ia32_bextri_u32 (unsigned int,
                                        const unsigned int);
unsigned long long __builtin_ia32_bextri_u64 (unsigned long long,
                                              const unsigned long long);
```

The following built-in functions are available when `-m3dnow` is used. All of them generate the machine instruction that is part of the name.

```
void __builtin_ia32_femms (void);
v8qi __builtin_ia32_pavgusb (v8qi, v8qi);
v2si __builtin_ia32_pf2id (v2sf);
v2sf __builtin_ia32_pfacc (v2sf, v2sf);
```

```
v2sf __builtin_ia32_pfadd (v2sf, v2sf);
v2si __builtin_ia32_pfcmpeq (v2sf, v2sf);
v2si __builtin_ia32_pfcmpge (v2sf, v2sf);
v2si __builtin_ia32_pfcmpgt (v2sf, v2sf);
v2sf __builtin_ia32_pfmax (v2sf, v2sf);
v2sf __builtin_ia32_pfmin (v2sf, v2sf);
v2sf __builtin_ia32_pfmul (v2sf, v2sf);
v2sf __builtin_ia32_pfrcp (v2sf);
v2sf __builtin_ia32_pfrcpit1 (v2sf, v2sf);
v2sf __builtin_ia32_pfrcpit2 (v2sf, v2sf);
v2sf __builtin_ia32_pfrsqrt (v2sf);
v2sf __builtin_ia32_pfsub (v2sf, v2sf);
v2sf __builtin_ia32_pfsubr (v2sf, v2sf);
v2sf __builtin_ia32_pi2fd (v2si);
v4hi __builtin_ia32_pmulhrw (v4hi, v4hi);
```

The following built-in functions are available when `-m3dnowa` is used. All of them generate the machine instruction that is part of the name.

```
v2si __builtin_ia32_pf2iw (v2sf);
v2sf __builtin_ia32_pfnacc (v2sf, v2sf);
v2sf __builtin_ia32_pfpnacc (v2sf, v2sf);
v2sf __builtin_ia32_pi2fw (v2si);
v2sf __builtin_ia32_pswapdsf (v2sf);
v2si __builtin_ia32_pswapdsi (v2si);
```

The following built-in functions are available when `-mrtm` is used They are used for restricted transactional memory. These are the internal low level functions. Normally the functions in Section 7.13.38 [x86 transactional memory intrinsics], page 1057, should be used instead.

```
int __builtin_ia32_xbegin ();
void __builtin_ia32_xend ();
void __builtin_ia32_xabort (status);
int __builtin_ia32_xtest ();
```

The following built-in functions are available when `-mmwaitx` is used. All of them generate the machine instruction that is part of the name.

```
void __builtin_ia32_monitorx (void *, unsigned int, unsigned int);
void __builtin_ia32_mwaitx (unsigned int, unsigned int, unsigned int);
```

The following built-in functions are available when `-mclzero` is used. All of them generate the machine instruction that is part of the name.

```
void __builtin_i32_clzero (void *);
```

The following built-in functions are available when `-mpku` is used. They generate reads and writes to PKRU.

```
void __builtin_ia32_wrpkru (unsigned int);
unsigned int __builtin_ia32_rdpkru ();
```

The following built-in functions are available when `-mshstk` option is used. They support shadow stack machine instructions from Intel Control-flow Enforcement Technology (CET). Each built-in function generates the machine instruction that is part of the function's name. These are the internal low-level functions. Normally the functions in Section 7.13.39 [x86 control-flow protection intrinsics], page 1058, should be used instead.

```
unsigned int __builtin_ia32_rdsspd (void);
unsigned long long __builtin_ia32_rdsspq (void);
void __builtin_ia32_incsspd (unsigned int);
void __builtin_ia32_incsspq (unsigned long long);
```

```
void __builtin_ia32_saveprevssp(void);
void __builtin_ia32_rstorssp(void *);
void __builtin_ia32_wrssd(unsigned int, void *);
void __builtin_ia32_wrssq(unsigned long long, void *);
void __builtin_ia32_wrussd(unsigned int, void *);
void __builtin_ia32_wrussq(unsigned long long, void *);
void __builtin_ia32_setssbsy(void);
void __builtin_ia32_clrssbsy(void *);
```

7.13.38 x86 Transactional Memory Intrinsics

These hardware transactional memory intrinsics for x86 allow you to use memory transactions with RTM (Restricted Transactional Memory). This support is enabled with the `-mrtm` option. For using HLE (Hardware Lock Elision) see [x86 specific memory model extensions for transactional memory], page 855, instead.

A memory transaction commits all changes to memory in an atomic way, as visible to other threads. If the transaction fails it is rolled back and all side effects discarded.

Generally there is no guarantee that a memory transaction ever succeeds and suitable fallback code always needs to be supplied.

`unsigned _xbegin ()` [RTM Function]

Start a RTM (Restricted Transactional Memory) transaction. Returns `_XBEGIN_STARTED` when the transaction started successfully (note this is not 0, so the constant has to be explicitly tested).

If the transaction aborts, all side effects are undone and an abort code encoded as a bit mask is returned. The following macros are defined:

`_XABORT_EXPLICIT` [Macro]

Transaction was explicitly aborted with `_xabort`. The parameter passed to `_xabort` is available with `_XABORT_CODE(status)`.

`_XABORT_RETRY` [Macro]

Transaction retry is possible.

`_XABORT_CONFLICT` [Macro]

Transaction abort due to a memory conflict with another thread.

`_XABORT_CAPACITY` [Macro]

Transaction abort due to the transaction using too much memory.

`_XABORT_DEBUG` [Macro]

Transaction abort due to a debug trap.

`_XABORT_NESTED` [Macro]

Transaction abort in an inner nested transaction.

There is no guarantee any transaction ever succeeds, so there always needs to be a valid fallback path.

`void _xend ()` [RTM Function]

Commit the current transaction. When no transaction is active this faults. All memory side effects of the transaction become visible to other threads in an atomic manner.

`int _xtest ()` [RTM Function]

Return a nonzero value if a transaction is currently active, otherwise 0.

`void _xabort (status)` [RTM Function]

Abort the current transaction. When no transaction is active this is a no-op. The *status* is an 8-bit constant; its value is encoded in the return value from `_xbegin`.

Here is an example showing handling for `_XABORT_RETRY` and a fallback path for other failures:

```
#include <immintrin.h>

int n_tries, max_tries;
unsigned status = _XABORT_EXPLICIT;
...

for (n_tries = 0; n_tries < max_tries; n_tries++)
  {
    status = _xbegin ();
    if (status == _XBEGIN_STARTED || !(status & _XABORT_RETRY))
      break;
  }
if (status == _XBEGIN_STARTED)
  {
    ... transaction code...
    _xend ();
  }
else
  {
    ... non-transactional fallback path...
  }
```

Note that, in most cases, the transactional and non-transactional code must synchronize together to ensure consistency.

7.13.39 x86 Control-Flow Protection Intrinsics

`ret_type _get_ssp (void)` [CET Function]

Get the current value of shadow stack pointer if shadow stack support from Intel CET is enabled in the hardware or `0` otherwise. The `ret_type` is `unsigned long long` for 64-bit targets and `unsigned int` for 32-bit targets.

`void _inc_ssp (unsigned int)` [CET Function]

Increment the current shadow stack pointer by the size specified by the function argument. The argument is masked to a byte value for security reasons, so to increment by more than 255 bytes you must call the function multiple times.

The shadow stack unwind code looks like:

```
#include <immintrin.h>

/* Unwind the shadow stack for EH.  */
#define _Unwind_Frames_Extra(x)       \
  do                                  \
    {                                 \
      _Unwind_Word ssp = _get_ssp (); \
      if (ssp != 0)                   \
```

```
    {                             \
      _Unwind_Word tmp = (x);     \
      while (tmp > 255)           \
        {                         \
          _inc_ssp (tmp);         \
          tmp -= 255;             \
        }                         \
      _inc_ssp (tmp);             \
    }                             \
}                                 \
while (0)
```

This code runs unconditionally on all 64-bit processors. For 32-bit processors the code runs on those that support multi-byte NOP instructions.

8 Extensions to the C++ Language

The GNU compiler provides these extensions to the C++ language (and you can also use most of the C language extensions in your C++ programs). If you want to write code that checks whether these features are available, you can test for the GNU compiler the same way as for C programs: check for a predefined macro `__GNUC__`. You can also use `__GNUG__` to test specifically for GNU C++ (see Section "Predefined Macros" in *The GNU C Preprocessor*).

8.1 When is a Volatile C++ Object Accessed?

The C++ standard differs from the C standard in its treatment of volatile objects. It fails to specify what constitutes a volatile access, except to say that C++ should behave in a similar manner to C with respect to volatiles, where possible. However, the different lvalueness of expressions between C and C++ complicate the behavior. G++ behaves the same as GCC for volatile access, See Chapter 6 [Volatiles], page 603, for a description of GCC's behavior.

The C and C++ language specifications differ when an object is accessed in a void context:

```
volatile int *src = somevalue;
*src;
```

The C++ standard specifies that such expressions do not undergo lvalue to rvalue conversion, and that the type of the dereferenced object may be incomplete. The C++ standard does not specify explicitly that it is lvalue to rvalue conversion that is responsible for causing an access. There is reason to believe that it is, because otherwise certain simple expressions become undefined. However, because it would surprise most programmers, G++ treats dereferencing a pointer to volatile object of complete type as GCC would do for an equivalent type in C. When the object has incomplete type, G++ issues a warning; if you wish to force an error, you must force a conversion to rvalue with, for instance, a static cast.

When using a reference to volatile, G++ does not treat equivalent expressions as accesses to volatiles, but instead issues a warning that no volatile is accessed. The rationale for this is that otherwise it becomes difficult to determine where volatile access occur, and not possible to ignore the return value from functions returning volatile references. Again, if you wish to force a read, cast the reference to an rvalue.

G++ implements the same behavior as GCC does when assigning to a volatile object—there is no reread of the assigned-to object, the assigned rvalue is reused. Note that in C++ assignment expressions are lvalues, and if used as an lvalue, the volatile object is referred to. For instance, *vref* refers to *vobj*, as expected, in the following example:

```
volatile int vobj;
volatile int &vref = vobj = something;
```

8.2 Restricting Pointer Aliasing

As with the C front end, G++ understands the C99 feature of restricted pointers, specified with the `__restrict__`, or `__restrict` type qualifier. Because you cannot compile C++ by specifying the `-std=c99` language flag, `restrict` is not a keyword in C++.

In addition to allowing restricted pointers, you can specify restricted references, which indicate that the reference is not aliased in the local context.

```
void fn (int *__restrict__ rptr, int &__restrict__ rref)
```

```
{
  /* ... */
}
```

In the body of `fn`, *rptr* points to an unaliased integer and *rref* refers to a (different) unaliased integer.

You may also specify whether a member function's *this* pointer is unaliased by using `__restrict__` as a member function qualifier.

```
void T::fn () __restrict__
{
  /* ... */
}
```

Within the body of `T::fn`, *this* has the effective definition `T *__restrict__ const this`. Notice that the interpretation of a `__restrict__` member function qualifier is different to that of `const` or `volatile` qualifier, in that it is applied to the pointer rather than the object. This is consistent with other compilers that implement restricted pointers.

As with all outermost parameter qualifiers, `__restrict__` is ignored in function definition matching. This means you only need to specify `__restrict__` in a function definition, rather than in a function prototype as well.

8.3 Vague Linkage

There are several constructs in C++ that require space in the object file but are not clearly tied to a single translation unit. We say that these constructs have "vague linkage". Typically such constructs are emitted wherever they are needed, though sometimes we can be more clever.

Inline Functions

Inline functions are typically defined in a header file which can be included in many different compilations. Hopefully they can usually be inlined, but sometimes an out-of-line copy is necessary, if the address of the function is taken or if inlining fails. In general, we emit an out-of-line copy in all translation units where one is needed. As an exception, we only emit inline virtual functions with the vtable, since it always requires a copy.

Local static variables and string constants used in an inline function are also considered to have vague linkage, since they must be shared between all inlined and out-of-line instances of the function.

VTables

C++ virtual functions are implemented in most compilers using a lookup table, known as a vtable. The vtable contains pointers to the virtual functions provided by a class, and each object of the class contains a pointer to its vtable (or vtables, in some multiple-inheritance situations). If the class declares any non-inline, non-pure virtual functions, the first one is chosen as the "key method" for the class, and the vtable is only emitted in the translation unit where the key method is defined.

Note: If the chosen key method is later defined as inline, the vtable is still emitted in every translation unit that defines it. Make sure that any inline virtuals are declared inline in the class body, even if they are not defined there.

`type_info` objects
: C++ requires information about types to be written out in order to implement '`dynamic_cast`', '`typeid`' and exception handling. For polymorphic classes (classes with virtual functions), the '`type_info`' object is written out along with the vtable so that '`dynamic_cast`' can determine the dynamic type of a class object at run time. For all other types, we write out the '`type_info`' object when it is used: when applying '`typeid`' to an expression, throwing an object, or referring to a type in a catch clause or exception specification.

Template Instantiations
: Most everything in this section also applies to template instantiations, but there are other options as well. See Section 8.5 [Where's the Template?], page 1064.

When used with GNU ld version 2.8 or later on an ELF system such as GNU/Linux or Solaris 2, or on Microsoft Windows, duplicate copies of these constructs will be discarded at link time. This is known as COMDAT support.

On targets that don't support COMDAT, but do support weak symbols, GCC uses them. This way one copy overrides all the others, but the unused copies still take up space in the executable.

For targets that do not support either COMDAT or weak symbols, most entities with vague linkage are emitted as local symbols to avoid duplicate definition errors from the linker. This does not happen for local statics in inlines, however, as having multiple copies almost certainly breaks things.

See Section 8.4 [Declarations and Definitions in One Header], page 1063, for another way to control placement of these constructs.

8.4 C++ Interface and Implementation Pragmas

`#pragma interface` and `#pragma implementation` provide the user with a way of explicitly directing the compiler to emit entities with vague linkage (and debugging information) in a particular translation unit.

Note: These `#pragma`s have been superseded as of GCC 2.7.2 by COMDAT support and the "key method" heuristic mentioned in Section 8.3 [Vague Linkage], page 1062. Using them can actually cause your program to grow due to unnecessary out-of-line copies of inline functions.

`#pragma interface`
`#pragma interface "`*`subdir/objects.h`*`"`
: Use this directive in *header files* that define object classes, to save space in most of the object files that use those classes. Normally, local copies of certain information (backup copies of inline member functions, debugging information, and the internal tables that implement virtual functions) must be kept in each object file that includes class definitions. You can use this pragma to avoid such duplication. When a header file containing '`#pragma interface`' is included in a compilation, this auxiliary information is not generated (unless the main input source file itself uses '`#pragma implementation`'). Instead, the object files contain references to be resolved at link time.

The second form of this directive is useful for the case where you have multiple headers with the same name in different directories. If you use this form, you must specify the same string to '`#pragma implementation`'.

`#pragma implementation`
`#pragma implementation "`*`objects`*`.h"`

Use this pragma in a *main input file*, when you want full output from included header files to be generated (and made globally visible). The included header file, in turn, should use '`#pragma interface`'. Backup copies of inline member functions, debugging information, and the internal tables used to implement virtual functions are all generated in implementation files.

If you use '`#pragma implementation`' with no argument, it applies to an include file with the same basename[1] as your source file. For example, in `allclass.cc`, giving just '`#pragma implementation`' by itself is equivalent to '`#pragma implementation "allclass.h"`'.

Use the string argument if you want a single implementation file to include code from multiple header files. (You must also use '`#include`' to include the header file; '`#pragma implementation`' only specifies how to use the file—it doesn't actually include it.)

There is no way to split up the contents of a single header file into multiple implementation files.

'`#pragma implementation`' and '`#pragma interface`' also have an effect on function inlining.

If you define a class in a header file marked with '`#pragma interface`', the effect on an inline function defined in that class is similar to an explicit `extern` declaration—the compiler emits no code at all to define an independent version of the function. Its definition is used only for inlining with its callers.

Conversely, when you include the same header file in a main source file that declares it as '`#pragma implementation`', the compiler emits code for the function itself; this defines a version of the function that can be found via pointers (or by callers compiled without inlining). If all calls to the function can be inlined, you can avoid emitting the function by compiling with `-fno-implement-inlines`. If any calls are not inlined, you will get linker errors.

8.5 Where's the Template?

C++ templates were the first language feature to require more intelligence from the environment than was traditionally found on a UNIX system. Somehow the compiler and linker have to make sure that each template instance occurs exactly once in the executable if it is needed, and not at all otherwise. There are two basic approaches to this problem, which are referred to as the Borland model and the Cfront model.

Borland model

Borland C++ solved the template instantiation problem by adding the code equivalent of common blocks to their linker; the compiler emits template in-

[1] A file's *basename* is the name stripped of all leading path information and of trailing suffixes, such as '`.h`' or '`.C`' or '`.cc`'.

stances in each translation unit that uses them, and the linker collapses them together. The advantage of this model is that the linker only has to consider the object files themselves; there is no external complexity to worry about. The disadvantage is that compilation time is increased because the template code is being compiled repeatedly. Code written for this model tends to include definitions of all templates in the header file, since they must be seen to be instantiated.

Cfront model
: The AT&T C++ translator, Cfront, solved the template instantiation problem by creating the notion of a template repository, an automatically maintained place where template instances are stored. A more modern version of the repository works as follows: As individual object files are built, the compiler places any template definitions and instantiations encountered in the repository. At link time, the link wrapper adds in the objects in the repository and compiles any needed instances that were not previously emitted. The advantages of this model are more optimal compilation speed and the ability to use the system linker; to implement the Borland model a compiler vendor also needs to replace the linker. The disadvantages are vastly increased complexity, and thus potential for error; for some code this can be just as transparent, but in practice it can been very difficult to build multiple programs in one directory and one program in multiple directories. Code written for this model tends to separate definitions of non-inline member templates into a separate file, which should be compiled separately.

G++ implements the Borland model on targets where the linker supports it, including ELF targets (such as GNU/Linux), macOS and Microsoft Windows. Otherwise G++ implements neither automatic model.

You have the following options for dealing with template instantiations:

1. Do nothing. Code written for the Borland model works fine, but each translation unit contains instances of each of the templates it uses. The duplicate instances will be discarded by the linker, but in a large program, this can lead to an unacceptable amount of code duplication in object files or shared libraries.

   Duplicate instances of a template can be avoided by defining an explicit instantiation in one object file, and preventing the compiler from doing implicit instantiations in any other object files by using an explicit instantiation declaration, using the `extern template` syntax:

   ```
   extern template int max (int, int);
   ```

   This syntax is defined in the C++ 2011 standard, but has been supported by G++ and other compilers since well before 2011.

   Explicit instantiations can be used for the largest or most frequently duplicated instances, without having to know exactly which other instances are used in the rest of the program. You can scatter the explicit instantiations throughout your program, perhaps putting them in the translation units where the instances are used or the translation units that define the templates themselves; you can put all of the explicit instantiations you need into one big file; or you can create small files like

   ```
   #include "Foo.h"
   ```

```
#include "Foo.cc"

template class Foo<int>;
template ostream& operator <<
                (ostream&, const Foo<int>&);
```

for each of the instances you need, and create a template instantiation library from those.

This is the simplest option, but also offers flexibility and fine-grained control when necessary. It is also the most portable alternative and programs using this approach will work with most modern compilers.

2. Compile your code with `-fno-implicit-templates` to disable the implicit generation of template instances, and explicitly instantiate all the ones you use. This approach requires more knowledge of exactly which instances you need than do the others, but it's less mysterious and allows greater control if you want to ensure that only the intended instances are used.

   If you are using Cfront-model code, you can probably get away with not using `-fno-implicit-templates` when compiling files that don't '`#include`' the member template definitions.

   If you use one big file to do the instantiations, you may want to compile it without `-fno-implicit-templates` so you get all of the instances required by your explicit instantiations (but not by any other files) without having to specify them as well.

   In addition to forward declaration of explicit instantiations (with `extern`), G++ has extended the template instantiation syntax to support instantiation of the compiler support data for a template class (i.e. the vtable) without instantiating any of its members (with `inline`), and instantiation of only the static data members of a template class, without the support data or member functions (with `static`):

```
inline template class Foo<int>;
static template class Foo<int>;
```

8.6 Extracting the Function Pointer from a Bound Pointer to Member Function

In C++, pointer to member functions (PMFs) are implemented using a wide pointer of sorts to handle all the possible call mechanisms; the PMF needs to store information about how to adjust the '`this`' pointer, and if the function pointed to is virtual, where to find the vtable, and where in the vtable to look for the member function. If you are using PMFs in an inner loop, you should really reconsider that decision. If that is not an option, you can extract the pointer to the function that would be called for a given object/PMF pair and call it directly inside the inner loop, to save a bit of time.

Note that you still pay the penalty for the call through a function pointer; on most modern architectures, such a call defeats the branch prediction features of the CPU. This is also true of normal virtual function calls.

The syntax for this extension is

```
extern A a;
extern int (A::*fp)();
typedef int (*fptr)(A *);
```

```
fptr p = (fptr)(a.*fp);
```

For PMF constants (i.e. expressions of the form '`&Klasse::Member`'), no object is needed to obtain the address of the function. They can be converted to function pointers directly:

```
fptr p1 = (fptr)(&A::foo);
```

You must specify `-Wno-pmf-conversions` to use this extension.

8.7 C++-Specific Variable, Function, and Type Attributes

Some attributes only make sense for C++ programs.

`abi_tag ("tag", ...)`

The `abi_tag` attribute can be applied to a function, variable, or class declaration. It modifies the mangled name of the entity to incorporate the tag name, in order to distinguish the function or class from an earlier version with a different ABI; perhaps the class has changed size, or the function has a different return type that is not encoded in the mangled name.

The attribute can also be applied to an inline namespace, but does not affect the mangled name of the namespace; in this case it is only used for `-Wabi-tag` warnings and automatic tagging of functions and variables. Tagging inline namespaces is generally preferable to tagging individual declarations, but the latter is sometimes necessary, such as when only certain members of a class need to be tagged.

The argument can be a list of strings of arbitrary length. The strings are sorted on output, so the order of the list is unimportant.

A redeclaration of an entity must not add new ABI tags, since doing so would change the mangled name.

The ABI tags apply to a name, so all instantiations and specializations of a template have the same tags. The attribute will be ignored if applied to an explicit specialization or instantiation.

The `-Wabi-tag` flag enables a warning about a class which does not have all the ABI tags used by its subobjects and virtual functions; for users with code that needs to coexist with an earlier ABI, using this option can help to find all affected types that need to be tagged.

When a type involving an ABI tag is used as the type of a variable or return type of a function where that tag is not already present in the signature of the function, the tag is automatically applied to the variable or function. `-Wabi-tag` also warns about this situation; this warning can be avoided by explicitly tagging the variable or function or moving it into a tagged inline namespace.

`init_priority (priority)`

In Standard C++, objects defined at namespace scope are guaranteed to be initialized in an order in strict accordance with that of their definitions *in a given translation unit*. No guarantee is made for initializations across translation units. However, GNU C++ allows you to control the order of initialization of objects defined at namespace scope with the `init_priority` attribute by specifying a relative *priority*, with the same meaning as for the `constructor` attribute (see Section 6.4.1.1 [Common Function Attributes], page 622).

In the following example, `A` would normally be created before `B`, but the `init_priority` attribute reverses that order:

```
Some_Class  A  __attribute__ ((init_priority (2000)));
Some_Class  B  __attribute__ ((init_priority (543)));
```

Note that the particular values of *priority* do not matter; only their relative ordering.

As with the *priority* argument to the `constructor` and `destructor` attributes, a few targets do not support the `init_priority` attribute. In that case the attribute is rejected with an error rather than ignored.

`no_dangling`

This attribute can be applied on a class type, function, or member function. Dangling references to classes marked with this attribute will have the `-Wdangling-reference` diagnostic suppressed; so will references returned from the `gnu::no_dangling`-marked functions. For example:

```
class [[gnu::no_dangling]] S { ... };
```

Or:

```
class A {
  int *p;
  [[gnu::no_dangling]] int &foo() { return *p; }
};

[[gnu::no_dangling]] const int &
foo (const int &i)
{
  ...
}
```

This attribute takes an optional argument, which must be an expression that evaluates to true or false:

```
template <typename T>
struct [[gnu::no_dangling(std::is_reference_v<T>)]] S {
  ...
};
```

Or:

```
template <typename T>
[[gnu::no_dangling(std::is_lvalue_reference_v<T>)]]
decltype(auto) foo(T&& t) {
  ...
};
```

`warn_unused`

For C++ types with non-trivial constructors and/or destructors it is impossible for the compiler to determine whether a variable of this type is truly unused if it is not referenced. This type attribute informs the compiler that variables of this type should be warned about if they appear to be unused, just like variables of fundamental types.

This attribute is appropriate for types which just represent a value, such as `std::string`; it is not appropriate for types which control a resource, such as `std::lock_guard`.

This attribute is also accepted in C, but it is unnecessary because C does not have constructors or destructors.

`cold`

In addition to functions and labels, GNU C++ allows the `cold` attribute to be used on C++ classes, structs, or unions. Applying the `cold` attribute on a type has the effect of treating every member function of the type, including implicit special member functions, as cold. If a member function is marked with the `hot` function attribute, the `hot` attribute takes precedence and the `cold` attribute is not propagated.

For the effects of the `cold` attribute on functions, see Section 6.4.1.1 [Common Function Attributes], page 622.

`hot`

In addition to functions and labels, GNU C++ allows the `hot` attribute to be used on C++ classes, structs, or unions. Applying the `hot` attribute on a type has the effect of treating every member function of the type, including implicit special member functions, as hot. If a member function is marked with the `cold` function attribute, the `cold` attribute takes precedence and the `hot` attribute is not propagated.

For the effects of the `hot` attribute on functions, see Section 6.4.1.1 [Common Function Attributes], page 622.

8.8 Function Multiversioning

Function multiversioning is a mechanism that enables compiling multiple versions of a function, each specialized for different combinations of architecture extensions. Additionally, the compiler generates a resolver that the dynamic linker uses to detect architecture support and choose the appropriate version at runtime.

Function multiversioning relies on the indirect function extension to the ELF standard, and therefore Binutils version 2.20.1 or higher and GNU C Library version 2.11.1 are required to use this feature.

There are two versions of function multiversioning supported by GCC.

For targets supporting the `target_version` attribute (AArch64 and RISC-V), when compiling for C or C++, a function version set can be defined by a combination of function definitions with `target_version` and `target_clones` attributes, across translation units.

For example:

```
// fmv.h:
int foo ();
int foo [[gnu::target_clones("sve", "sve2")]] ();
int foo [[gnu::target_version("dotprod;priority=1")]] ();

// fmv1.cc
#include "fmv.h"

int foo ()
{
  // The default version of foo.
  return 0;
}

// fmv2.cc:
```

```
#include "fmv.h"

int foo [[gnu::target_clones("sve", "sve2")]] ()
{
  // foo versions for sve and sve2
  return 1;
}

int foo [[gnu::target_version("dotprod")]] ()
{
  // foo version for dotprod extension
  return 2;
}

// main.cc
#include "fmv.h"

int main ()
{
  int (*p)() = &foo;
  assert ((*p) () == foo ());
  return 0;
}
```

This example results in 4 versions of the foo function being generated, and a resolver which is used by the dynamic linker to choose the correct version.

For the AArch64 target GCC implements function multiversionsing, with the semantics and version strings as specified in the Section 7.13.5 [Arm C Language Extensions (ACLE)], page 882.

For targets that support multiversioning with the `target` attribute (x86) a multiversioned function can be defined with either multiple function definitions with the `target` attribute (in C++) within a translation unit, or a single definition with the `target_clones` attribute.

Here is an example.

```
__attribute__ ((target ("default")))
int foo ()
{
  // The default version of foo.
  return 0;
}

__attribute__ ((target ("sse4.2")))
int foo ()
{
  // foo version for SSE4.2
  return 1;
}

__attribute__ ((target ("arch=atom")))
int foo ()
{
  // foo version for the Intel ATOM processor
  return 2;
}

__attribute__ ((target ("arch=amdfam10")))
int foo ()
```

```
{
  // foo version for the AMD Family 0x10 processors.
  return 3;
}

int main ()
{
  int (*p)() = &foo;
  assert ((*p) () == foo ());
  return 0;
}
```

In the above example, four versions of function foo are created. The first version of foo with the target attribute "default" is the default version. This version gets executed when no other target specific version qualifies for execution on a particular platform. A new version of foo is created by using the same function signature but with a different target string. Function foo is called or a pointer to it is taken just like a regular function. GCC takes care of doing the dispatching to call the right version at runtime. Refer to the GCC wiki on Function Multiversioning (`https://gcc.gnu.org/wiki/FunctionMultiVersioning`) for more details.

8.9 Type Traits

The C++ front end implements syntactic extensions that allow compile-time determination of various characteristics of a type (or of a pair of types).

`bool __has_nothrow_assign (`*type*`)` [Built-in Function]

If *type* is `const`-qualified or is a reference type then the trait is `false`. Otherwise if `__has_trivial_assign (type)` is `true` then the trait is `true`, else if *type* is a cv-qualified class or union type with copy assignment operators that are known not to throw an exception then the trait is `true`, else it is `false`. Requires: *type* shall be a complete type, (possibly cv-qualified) `void`, or an array of unknown bound.

`bool __has_nothrow_copy (`*type*`)` [Built-in Function]

If `__has_trivial_copy (type)` is `true` then the trait is `true`, else if *type* is a cv-qualified class or union type with copy constructors that are known not to throw an exception then the trait is `true`, else it is `false`. Requires: *type* shall be a complete type, (possibly cv-qualified) `void`, or an array of unknown bound.

`bool __has_nothrow_constructor (`*type*`)` [Built-in Function]

If `__has_trivial_constructor (type)` is `true` then the trait is `true`, else if *type* is a cv class or union type (or array thereof) with a default constructor that is known not to throw an exception then the trait is `true`, else it is `false`. Requires: *type* shall be a complete type, (possibly cv-qualified) `void`, or an array of unknown bound.

`bool __has_trivial_assign (`*type*`)` [Built-in Function]

If *type* is `const`- qualified or is a reference type then the trait is `false`. Otherwise if `__is_trivial (type)` is `true` then the trait is `true`, else if *type* is a cv-qualified class or union type with a trivial copy assignment ([class.copy]) then the trait is `true`, else it is `false`. Requires: *type* shall be a complete type, (possibly cv-qualified) `void`, or an array of unknown bound.

`bool __has_trivial_copy (type)` [Built-in Function]

If `__is_trivial (type)` is `true` or *type* is a reference type then the trait is `true`, else if *type* is a cv class or union type with a trivial copy constructor ([class.copy]) then the trait is `true`, else it is `false`. Requires: *type* shall be a complete type, (possibly cv-qualified) `void`, or an array of unknown bound.

`bool __has_trivial_constructor (type)` [Built-in Function]

If `__is_trivial (type)` is `true` then the trait is `true`, else if *type* is a cv-qualified class or union type (or array thereof) with a trivial default constructor ([class.ctor]) then the trait is `true`, else it is `false`. Requires: *type* shall be a complete type, (possibly cv-qualified) `void`, or an array of unknown bound.

`bool __has_trivial_destructor (type)` [Built-in Function]

If `__is_trivial (type)` is `true` or *type* is a reference type then the trait is `true`, else if *type* is a cv class or union type (or array thereof) with a trivial destructor ([class.dtor]) then the trait is `true`, else it is `false`. Requires: *type* shall be a complete type, (possibly cv-qualified) `void`, or an array of unknown bound.

`bool __has_virtual_destructor (type)` [Built-in Function]

If *type* is a class type with a virtual destructor ([class.dtor]) then the trait is `true`, else it is `false`. Requires: If *type* is a non-union class type, it shall be a complete type.

`bool __is_abstract (type)` [Built-in Function]

If *type* is an abstract class ([class.abstract]) then the trait is `true`, else it is `false`. Requires: If *type* is a non-union class type, it shall be a complete type.

`bool __is_aggregate (type)` [Built-in Function]

If *type* is an aggregate type ([dcl.init.aggr]) the trait is `true`, else it is `false`. Requires: If *type* is a class type, it shall be a complete type.

`bool __is_base_of (base_type, derived_type)` [Built-in Function]

If *base_type* is a base class of *derived_type* ([class.derived]) then the trait is `true`, otherwise it is `false`. Top-level cv-qualifications of *base_type* and *derived_type* are ignored. For the purposes of this trait, a class type is considered is own base. The trait is `true` even if *base_type* is an ambiguous or inaccessible base class of *derived_type*. Requires: if `__is_class (base_type)` and `__is_class (derived_type)` are `true` and *base_type* and *derived_type* are not the same type (disregarding cv-qualifiers), *derived_type* shall be a complete type. A diagnostic is produced if this requirement is not met.

`bool __builtin_is_virtual_base_of (base_type, derived_type)` [Built-in Function]

If *base_type* is a virtual base class of *derived_type* ([class.derived], [class.mi]) then the trait is `true`, otherwise it is `false`. Top-level cv-qualifications of *base_type* and *derived_type* are ignored. The trait is `true` even if *base_type* is an ambiguous or inaccessible virtual base class of *derived_type*. Requires: if `__is_class (base_type)` and `__is_class (derived_type)` are `true`, *derived_type* shall be a complete type. A diagnostic is produced if this requirement is not met.

`bool __is_class (type)` [Built-in Function]
If *type* is a cv-qualified class type, and not a union type ([basic.compound]) the trait is `true`, else it is `false`.

`bool __is_empty (type)` [Built-in Function]
If `__is_class (type)` is `false` then the trait is `false`. Otherwise *type* is considered empty if and only if: *type* has no non-static data members, or all non-static data members, if any, are bit-fields of length 0, and *type* has no virtual members, and *type* has no virtual base classes, and *type* has no base classes *base_type* for which `__is_empty (base_type)` is `false`. Requires: If *type* is a non-union class type, it shall be a complete type.

`bool __is_enum (type)` [Built-in Function]
If *type* is a cv enumeration type ([basic.compound]) the trait is `true`, else it is `false`.

`bool __is_final (type)` [Built-in Function]
If *type* is a class or union type marked `final`, then the trait is `true`, else it is `false`. Requires: If *type* is a class type, it shall be a complete type.

`bool __is_literal_type (type)` [Built-in Function]
If *type* is a literal type ([basic.types]) the trait is `true`, else it is `false`. Requires: *type* shall be a complete type, (possibly cv-qualified) `void`, or an array of unknown bound.

`bool __is_pod (type)` [Built-in Function]
If *type* is a cv POD type ([basic.types]) then the trait is `true`, else it is `false`. Requires: *type* shall be a complete type, (possibly cv-qualified) `void`, or an array of unknown bound.

`bool __is_polymorphic (type)` [Built-in Function]
If *type* is a polymorphic class ([class.virtual]) then the trait is `true`, else it is `false`. Requires: If *type* is a non-union class type, it shall be a complete type.

`bool __is_standard_layout (type)` [Built-in Function]
If *type* is a standard-layout type ([basic.types]) the trait is `true`, else it is `false`. Requires: *type* shall be a complete type, an array of complete types, or (possibly cv-qualified) `void`.

`bool __is_trivial (type)` [Built-in Function]
If *type* is a trivial type ([basic.types]) the trait is `true`, else it is `false`. Requires: *type* shall be a complete type, an array of complete types, or (possibly cv-qualified) `void`.

`bool __is_union (type)` [Built-in Function]
If *type* is a cv union type ([basic.compound]) the trait is `true`, else it is `false`.

`bool __underlying_type (type)` [Built-in Function]
The underlying type of *type*. Requires: *type* shall be an enumeration type ([dcl.enum]).

`bool __integer_pack (length)` [Built-in Function]

When used as the pattern of a pack expansion within a template definition, expands to a template argument pack containing integers from `0` to `length-1`. This is provided for efficient implementation of `std::make_integer_sequence`.

`bool __is_same (type1, type2)` [Built-in Function]

A binary type trait: `true` whenever the *type1* and *type2* refer to the same type.

`size_t __builtin_structured_binding_size (type)` [Built-in Function]

This trait returns the structured binding size ([dcl.struct.bind]) of *type*. If a type does not have a structured binding size, an error is diagnosed unless it is used in SFINAE contexts.

8.10 Deprecated Features

In the past, the GNU C++ compiler was extended to experiment with new features, at a time when the C++ language was still evolving. Now that the C++ standard is complete, some of those features are superseded by superior alternatives. Using the old features might cause a warning in some cases that the feature will be dropped in the future. In other cases, the feature might be gone already.

G++ allows a virtual function returning '`void *`' to be overridden by one returning a different pointer type. This extension to the covariant return type rules is now deprecated and will be removed from a future version.

The use of default arguments in function pointers, function typedefs and other places where they are not permitted by the standard is deprecated and will be removed from a future version of G++.

G++ allows attributes to follow a parenthesized direct initializer, e.g. '`int f (0) __attribute__ ((something));`' This extension has been ignored since G++ 3.3 and is deprecated.

G++ allows anonymous structs and unions to have members that are not public non-static data members (i.e. fields). These extensions are deprecated.

8.11 Backwards Compatibility

Now that there is a definitive ISO standard C++, G++ has a specification to adhere to. The C++ language evolved over time, and features that used to be acceptable in previous drafts of the standard, such as the ARM [Annotated C++ Reference Manual], are no longer accepted. In order to allow compilation of C++ written to such drafts, G++ contains some backwards compatibilities. *All such backwards compatibility features are liable to disappear in future versions of G++.* They should be considered deprecated. See Section 8.10 [Deprecated Features], page 1074.

`Implicit C language`

Old C system header files did not contain an `extern "C" {...}` scope to set the language. On such systems, all system header files are implicitly scoped inside a C language scope. Such headers must correctly prototype function argument types, there is no leeway for `()` to indicate an unspecified set of arguments.

9 GNU Objective-C Features

This document is meant to describe some of the GNU Objective-C features. It is not intended to teach you Objective-C. There are several resources on the Internet that present the language.

9.1 GNU Objective-C Runtime API

This section is specific for the GNU Objective-C runtime. If you are using a different runtime, you can skip it.

The GNU Objective-C runtime provides an API that allows you to interact with the Objective-C runtime system, querying the live runtime structures and even manipulating them. This allows you for example to inspect and navigate classes, methods and protocols; to define new classes or new methods, and even to modify existing classes or protocols.

If you are using a "Foundation" library such as GNUstep-Base, this library will provide you with a rich set of functionality to do most of the inspection tasks, and you probably will only need direct access to the GNU Objective-C runtime API to define new classes or methods.

9.1.1 Modern GNU Objective-C Runtime API

The GNU Objective-C runtime provides an API which is similar to the one provided by the "Objective-C 2.0" Apple/NeXT Objective-C runtime. The API is documented in the public header files of the GNU Objective-C runtime:

- `objc/objc.h`: this is the basic Objective-C header file, defining the basic Objective-C types such as `id`, `Class` and `BOOL`. You have to include this header to do almost anything with Objective-C.
- `objc/runtime.h`: this header declares most of the public runtime API functions allowing you to inspect and manipulate the Objective-C runtime data structures. These functions are fairly standardized across Objective-C runtimes and are almost identical to the Apple/NeXT Objective-C runtime ones. It does not declare functions in some specialized areas (constructing and forwarding message invocations, threading) which are in the other headers below. You have to include `objc/objc.h` and `objc/runtime.h` to use any of the functions, such as `class_getName()`, declared in `objc/runtime.h`.
- `objc/message.h`: this header declares public functions used to construct, deconstruct and forward message invocations. Because messaging is done in quite a different way on different runtimes, functions in this header are specific to the GNU Objective-C runtime implementation.
- `objc/objc-exception.h`: this header declares some public functions related to Objective-C exceptions. For example functions in this header allow you to throw an Objective-C exception from plain C/C++ code.
- `objc/objc-sync.h`: this header declares some public functions related to the Objective-C `@synchronized()` syntax, allowing you to emulate an Objective-C `@synchronized()` block in plain C/C++ code.
- `objc/thr.h`: this header declares a public runtime API threading layer that is only provided by the GNU Objective-C runtime. It declares functions such as `objc_mutex_lock()`, which provide a platform-independent set of threading functions.

The header files contain detailed documentation for each function in the GNU Objective-C runtime API.

9.1.2 Traditional GNU Objective-C Runtime API

The GNU Objective-C runtime used to provide a different API, which we call the "traditional" GNU Objective-C runtime API. Functions belonging to this API are easy to recognize because they use a different naming convention, such as `class_get_super_class()` (traditional API) instead of `class_getSuperclass()` (modern API). Software using this API includes the file `objc/objc-api.h` where it is declared.

Starting with GCC 4.7.0, the traditional GNU runtime API is no longer available.

9.2 `+load`: Executing Code before `main`

This section is specific for the GNU Objective-C runtime. If you are using a different runtime, you can skip it.

The GNU Objective-C runtime provides a way that allows you to execute code before the execution of the program enters the `main` function. The code is executed on a per-class and a per-category basis, through a special class method `+load`.

This facility is very useful if you want to initialize global variables which can be accessed by the program directly, without sending a message to the class first. The usual way to initialize global variables, in the `+initialize` method, might not be useful because `+initialize` is only called when the first message is sent to a class object, which in some cases could be too late.

Suppose for example you have a `FileStream` class that declares `Stdin`, `Stdout` and `Stderr` as global variables, like below:

```
FileStream *Stdin = nil;
FileStream *Stdout = nil;
FileStream *Stderr = nil;

@implementation FileStream

+ (void)initialize
{
    Stdin = [[FileStream new] initWithFd:0];
    Stdout = [[FileStream new] initWithFd:1];
    Stderr = [[FileStream new] initWithFd:2];
}

/* Other methods here */
@end
```

In this example, the initialization of `Stdin`, `Stdout` and `Stderr` in `+initialize` occurs too late. The programmer can send a message to one of these objects before the variables are actually initialized, thus sending messages to the `nil` object. The `+initialize` method which actually initializes the global variables is not invoked until the first message is sent to the class object. The solution would require these variables to be initialized just before entering `main`.

The correct solution of the above problem is to use the `+load` method instead of `+initialize`:

```
@implementation FileStream

+ (void)load
{
    Stdin = [[FileStream new] initWithFd:0];
    Stdout = [[FileStream new] initWithFd:1];
    Stderr = [[FileStream new] initWithFd:2];
}

/* Other methods here */
@end
```

The `+load` is a method that is not overridden by categories. If a class and a category of it both implement `+load`, both methods are invoked. This allows some additional initializations to be performed in a category.

This mechanism is not intended to be a replacement for `+initialize`. You should be aware of its limitations when you decide to use it instead of `+initialize`.

9.2.1 What You Can and Cannot Do in `+load`

`+load` is to be used only as a last resort. Because it is executed very early, most of the Objective-C runtime machinery will not be ready when `+load` is executed; hence `+load` works best for executing C code that is independent on the Objective-C runtime.

The `+load` implementation in the GNU runtime guarantees you the following things:

- you can write whatever C code you like;
- you can allocate and send messages to objects whose class is implemented in the same file;
- the `+load` implementation of all super classes of a class are executed before the `+load` of that class is executed;
- the `+load` implementation of a class is executed before the `+load` implementation of any category.

In particular, the following things, even if they can work in a particular case, are not guaranteed:

- allocation of or sending messages to arbitrary objects;
- allocation of or sending messages to objects whose classes have a category implemented in the same file;
- sending messages to Objective-C constant strings (`@"this is a constant string"`);

You should make no assumptions about receiving `+load` in sibling classes when you write `+load` of a class. The order in which sibling classes receive `+load` is not guaranteed.

The order in which `+load` and `+initialize` are called could be problematic if this matters. If you don't allocate objects inside `+load`, it is guaranteed that `+load` is called before `+initialize`. If you create an object inside `+load` the `+initialize` method of object's class is invoked even if `+load` was not invoked. Note if you explicitly call `+load` on a class,

`+initialize` will be called first. To avoid possible problems try to implement only one of these methods.

The `+load` method is also invoked when a bundle is dynamically loaded into your running program. This happens automatically without any intervening operation from you. When you write bundles and you need to write `+load` you can safely create and send messages to objects whose classes already exist in the running program. The same restrictions as above apply to classes defined in bundle.

9.3 Type Encoding

This is an advanced section. Type encodings are used extensively by the compiler and by the runtime, but you generally do not need to know about them to use Objective-C.

The Objective-C compiler generates type encodings for all the types. These type encodings are used at runtime to find out information about selectors and methods and about objects and classes.

The types are encoded in the following way:

`_Bool`	`B`
`char`	`c`
`unsigned char`	`C`
`short`	`s`
`unsigned short`	`S`
`int`	`i`
`unsigned int`	`I`
`long`	`l`
`unsigned long`	`L`
`long long`	`q`
`unsigned long long`	`Q`
`float`	`f`
`double`	`d`
`long double`	`D`
`void`	`v`
`id`	`@`
`Class`	`#`
`SEL`	`:`
`char*`	`*`
`enum`	an `enum` is encoded exactly as the integer type that the compiler uses for it, which depends on the enumeration values. Often the compiler users `unsigned int`, which is then encoded as `I`.
unknown type	`?`
Complex types	`j` followed by the inner type. For example `_Complex double` is encoded as `"jd"`.
bit-fields	`b` followed by the starting position of the bit-field, the type of the bit-field and the size of the bit-field (the bit-fields encoding was changed from the NeXT's compiler encoding, see below)

The encoding of bit-fields has changed to allow bit-fields to be properly handled by the runtime functions that compute sizes and alignments of types that contain bit-fields. The previous encoding contained only the size of the bit-field. Using only this information it is not possible to reliably compute the size occupied by the bit-field. This is very important in the presence of the Boehm's garbage collector because the objects are allocated using the typed memory facility available in this collector. The typed memory allocation requires information about where the pointers are located inside the object.

The position in the bit-field is the position, counting in bits, of the bit closest to the beginning of the structure.

The non-atomic types are encoded as follows:

pointers
: '`^`' followed by the pointed type.

arrays
: '`[`' followed by the number of elements in the array followed by the type of the elements followed by '`]`'

structures
: '`{`' followed by the name of the structure (or '`?`' if the structure is unnamed), the '`=`' sign, the type of the members and by '`}`'

unions
: '`(`' followed by the name of the structure (or '`?`' if the union is unnamed), the '`=`' sign, the type of the members followed by '`)`'

vectors
: '`![`' followed by the vector_size (the number of bytes composing the vector) followed by a comma, followed by the alignment (in bytes) of the vector, followed by the type of the elements followed by '`]`'

Here are some types and their encodings, as they are generated by the compiler on an i386 machine:

Objective-C type	**Compiler encoding**
`int a[10];`	`[10i]`
`struct { int i; float f[3]; int a:3; int b:2; char c; }`	`{?=i[3f]b128i3b131i2c}`
`int a __attribute__ ((vector_size (16)));`	`![16,16i]` (alignment depends on the machine)

In addition to the types the compiler also encodes the type specifiers. The table below describes the encoding of the current Objective-C type specifiers:

Specifier	**Encoding**
`const`	`r`
`in`	`n`
`inout`	`N`
`out`	`o`
`bycopy`	`O`
`byref`	`R`
`oneway`	`V`

The type specifiers are encoded just before the type. Unlike types however, the type specifiers are only encoded when they appear in method argument types.

Note how `const` interacts with pointers:

Objective-C type	**Compiler encoding**
`const int`	`ri`
`const int*`	`^ri`
`int *const`	`r^i`

`const int*` is a pointer to a `const int`, and so is encoded as `^ri`. `int* const`, instead, is a `const` pointer to an `int`, and so is encoded as `r^i`.

Finally, there is a complication when encoding `const char *` versus `char * const`. Because `char *` is encoded as `*` and not as `^c`, there is no way to express the fact that `r` applies to the pointer or to the pointee.

Hence, it is assumed as a convention that `r*` means `const char *` (since it is what is most often meant), and there is no way to encode `char *const`. `char *const` would simply be encoded as `*`, and the `const` is lost.

9.3.1 Legacy Type Encoding

Unfortunately, historically GCC used to have a number of bugs in its encoding code. The NeXT runtime expects GCC to emit type encodings in this historical format (compatible with GCC-3.3), so when using the NeXT runtime, GCC will introduce on purpose a number of incorrect encodings:

- the read-only qualifier of the pointee gets emitted before the '^'. The read-only qualifier of the pointer itself gets ignored, unless it is a typedef. Also, the 'r' is only emitted for the outermost type.
- 32-bit longs are encoded as 'l' or 'L', but not always. For typedefs, the compiler uses 'i' or 'I' instead if encoding a struct field or a pointer.
- `enum`s are always encoded as 'i' (int) even if they are actually unsigned or long.

In addition to that, the NeXT runtime uses a different encoding for bitfields. It encodes them as `b` followed by the size, without a bit offset or the underlying field type.

9.3.2 `@encode`

GNU Objective-C supports the `@encode` syntax that allows you to create a type encoding from a C/Objective-C type. For example, `@encode(int)` is compiled by the compiler into `"i"`.

`@encode` does not support type qualifiers other than `const`. For example, `@encode(const char*)` is valid and is compiled into `"r*"`, while `@encode(bycopy char *)` is invalid and will cause a compilation error.

9.3.3 Method Signatures

This section documents the encoding of method types, which is rarely needed to use Objective-C. You should skip it at a first reading; the runtime provides functions that will work on methods and can walk through the list of parameters and interpret them for you. These functions are part of the public "API" and are the preferred way to interact with method signatures from user code.

But if you need to debug a problem with method signatures and need to know how they are implemented (i.e., the "ABI"), read on.

Methods have their "signature" encoded and made available to the runtime. The "signature" encodes all the information required to dynamically build invocations of the method at runtime: return type and arguments.

The "signature" is a null-terminated string, composed of the following:

- The return type, including type qualifiers. For example, a method returning `int` would have `i` here.
- The total size (in bytes) required to pass all the parameters. This includes the two hidden parameters (the object `self` and the method selector `_cmd`).
- Each argument, with the type encoding, followed by the offset (in bytes) of the argument in the list of parameters.

For example, a method with no arguments and returning `int` would have the signature `i8@0:4` if the size of a pointer is 4. The signature is interpreted as follows: the `i` is the return type (an `int`), the `8` is the total size of the parameters in bytes (two pointers each of size 4), the `@0` is the first parameter (an object at byte offset `0`) and `:4` is the second parameter (a `SEL` at byte offset `4`).

You can easily find more examples by running the "strings" program on an Objective-C object file compiled by GCC. You'll see a lot of strings that look very much like `i8@0:4`. They are signatures of Objective-C methods.

9.4 Garbage Collection

This section is specific for the GNU Objective-C runtime. If you are using a different runtime, you can skip it.

Support for garbage collection with the GNU runtime has been added by using a powerful conservative garbage collector, known as the Boehm-Demers-Weiser conservative garbage collector.

To enable the support for it you have to configure the compiler using an additional argument, `--enable-objc-gc`. This will build the boehm-gc library, and build an additional runtime library which has several enhancements to support the garbage collector. The new library has a new name, `libobjc_gc.a` to not conflict with the non-garbage-collected library.

When the garbage collector is used, the objects are allocated using the so-called typed memory allocation mechanism available in the Boehm-Demers-Weiser collector. This mode requires precise information on where pointers are located inside objects. This information is computed once per class, immediately after the class has been initialized.

There is a new runtime function `class_ivar_set_gcinvisible()` which can be used to declare a so-called *weak pointer* reference. Such a pointer is basically hidden for the garbage collector; this can be useful in certain situations, especially when you want to keep track of the allocated objects, yet allow them to be collected. This kind of pointers can only be members of objects, you cannot declare a global pointer as a weak reference. Every type which is a pointer type can be declared a weak pointer, including `id`, `Class` and `SEL`.

Here is an example of how to use this feature. Suppose you want to implement a class whose instances hold a weak pointer reference; the following class does this:

```
@interface WeakPointer : Object
{
    const void* weakPointer;
}

- initWithPointer:(const void*)p;
- (const void*)weakPointer;
@end


@implementation WeakPointer

+ (void)initialize
{
  if (self == objc_lookUpClass ("WeakPointer"))
    class_ivar_set_gcinvisible (self, "weakPointer", YES);
}

- initWithPointer:(const void*)p
{
  weakPointer = p;
  return self;
}

- (const void*)weakPointer
{
  return weakPointer;
}

@end
```

Weak pointers are supported through a new type character specifier represented by the '`!`' character. The `class_ivar_set_gcinvisible()` function adds or removes this specifier to the string type description of the instance variable named as argument.

9.5 Constant String Objects

GNU Objective-C provides constant string objects that are generated directly by the compiler. You declare a constant string object by prefixing a C constant string with the character '`@`':

```
id myString = @"this is a constant string object";
```

The constant string objects are by default instances of the `NXConstantString` class which is provided by the GNU Objective-C runtime. To get the definition of this class you must include the `objc/NXConstStr.h` header file.

User defined libraries may want to implement their own constant string class. To be able to support them, the GNU Objective-C compiler provides a new command line options `-fconstant-string-class=class-name`. The provided class should adhere to a strict structure, the same as `NXConstantString`'s structure:

```
@interface MyConstantStringClass
{
  Class isa;
  char *c_string;
  unsigned int len;
}
@end
```

`NXConstantString` inherits from `Object`; user class libraries may choose to inherit the customized constant string class from a different class than `Object`. There is no requirement in the methods the constant string class has to implement, but the final ivar layout of the class must be the compatible with the given structure.

When the compiler creates the statically allocated constant string object, the `c_string` field will be filled by the compiler with the string; the `length` field will be filled by the compiler with the string length; the `isa` pointer will be filled with `NULL` by the compiler, and it will later be fixed up automatically at runtime by the GNU Objective-C runtime library to point to the class which was set by the `-fconstant-string-class` option when the object file is loaded (if you wonder how it works behind the scenes, the name of the class to use, and the list of static objects to fixup, are stored by the compiler in the object file in a place where the GNU runtime library will find them at runtime).

As a result, when a file is compiled with the `-fconstant-string-class` option, all the constant string objects will be instances of the class specified as argument to this option. It is possible to have multiple compilation units referring to different constant string classes, neither the compiler nor the linker impose any restrictions in doing this.

9.6 `compatibility_alias`

The keyword `@compatibility_alias` allows you to define a class name as equivalent to another class name. For example:

```
@compatibility_alias WOApplication GSWApplication;
```

tells the compiler that each time it encounters `WOApplication` as a class name, it should replace it with `GSWApplication` (that is, `WOApplication` is just an alias for `GSWApplication`).

There are some constraints on how this can be used—

- `WOApplication` (the alias) must not be an existing class;
- `GSWApplication` (the real class) must be an existing class.

9.7 Exceptions

GNU Objective-C provides exception support built into the language, as in the following example:

```
  @try {
    ...
       @throw expr;
    ...
```

```
}
@catch (AnObjCClass *exc) {
  ...
    @throw expr;
  ...
    @throw;
  ...
}
@catch (AnotherClass *exc) {
  ...
}
@catch (id allOthers) {
  ...
}
@finally {
  ...
    @throw expr;
  ...
}
```

The `@throw` statement may appear anywhere in an Objective-C or Objective-C++ program; when used inside of a `@catch` block, the `@throw` may appear without an argument (as shown above), in which case the object caught by the `@catch` will be rethrown.

Note that only (pointers to) Objective-C objects may be thrown and caught using this scheme. When an object is thrown, it will be caught by the nearest `@catch` clause capable of handling objects of that type, analogously to how `catch` blocks work in C++ and Java. A `@catch(id ...)` clause (as shown above) may also be provided to catch any and all Objective-C exceptions not caught by previous `@catch` clauses (if any).

The `@finally` clause, if present, will be executed upon exit from the immediately preceding `@try ... @catch` section. This will happen regardless of whether any exceptions are thrown, caught or rethrown inside the `@try ... @catch` section, analogously to the behavior of the `finally` clause in Java.

There are several caveats to using the new exception mechanism:

- The `-fobjc-exceptions` command line option must be used when compiling Objective-C files that use exceptions.
- With the GNU runtime, exceptions are always implemented as "native" exceptions and it is recommended that the `-fexceptions` and `-shared-libgcc` options are used when linking.
- With the NeXT runtime, although currently designed to be binary compatible with `NS_HANDLER`-style idioms provided by the `NSException` class, the new exceptions can only be used on Mac OS X 10.3 (Panther) and later systems, due to additional functionality needed in the NeXT Objective-C runtime.
- As mentioned above, the new exceptions do not support handling types other than Objective-C objects. Furthermore, when used from Objective-C++, the Objective-C exception model does not interoperate with C++ exceptions at this time. This means you cannot `@throw` an exception from Objective-C and `catch` it in C++, or vice versa (i.e., `throw ... @catch`).

9.8 Synchronization

GNU Objective-C provides support for synchronized blocks:

```
@synchronized (ObjCClass *guard) {
  ...
}
```

Upon entering the `@synchronized` block, a thread of execution shall first check whether a lock has been placed on the corresponding `guard` object by another thread. If it has, the current thread shall wait until the other thread relinquishes its lock. Once `guard` becomes available, the current thread will place its own lock on it, execute the code contained in the `@synchronized` block, and finally relinquish the lock (thereby making `guard` available to other threads).

Unlike Java, Objective-C does not allow for entire methods to be marked `@synchronized`. Note that throwing exceptions out of `@synchronized` blocks is allowed, and will cause the guarding object to be unlocked properly.

Because of the interactions between synchronization and exception handling, you can only use `@synchronized` when compiling with exceptions enabled, that is with the command line option `-fobjc-exceptions`.

9.9 Fast Enumeration

9.9.1 Using Fast Enumeration

GNU Objective-C provides support for the fast enumeration syntax:

```
id array = ...;
id object;

for (object in array)
{
  /* Do something with 'object' */
}
```

`array` needs to be an Objective-C object (usually a collection object, for example an array, a dictionary or a set) which implements the "Fast Enumeration Protocol" (see below). If you are using a Foundation library such as GNUstep Base or Apple Cocoa Foundation, all collection objects in the library implement this protocol and can be used in this way.

The code above would iterate over all objects in `array`. For each of them, it assigns it to `object`, then executes the `Do something with 'object'` statements.

Here is a fully worked-out example using a Foundation library (which provides the implementation of `NSArray`, `NSString` and `NSLog`):

```
NSArray *array = [NSArray arrayWithObjects: @"1", @"2", @"3", nil];
NSString *object;

for (object in array)
  NSLog (@"Iterating over %@", object);
```

9.9.2 C99-Like Fast Enumeration Syntax

A c99-like declaration syntax is also allowed:

```
id array = ...;
```

```
for (id object in array)
{
  /* Do something with 'object'  */
}
```

this is completely equivalent to:

```
id array = ...;

{
  id object;
  for (object in array)
  {
    /* Do something with 'object'  */
  }
}
```

but can save some typing.

Note that the option `-std=c99` is not required to allow this syntax in Objective-C.

9.9.3 Fast Enumeration Details

Here is a more technical description with the gory details. Consider the code

```
for (object expression in collection expression)
{
  statements
}
```

here is what happens when you run it:

- *`collection expression`* is evaluated exactly once and the result is used as the collection object to iterate over. This means it is safe to write code such as `for (object in [NSDictionary keyEnumerator]) ...`.
- the iteration is implemented by the compiler by repeatedly getting batches of objects from the collection object using the fast enumeration protocol (see below), then iterating over all objects in the batch. This is faster than a normal enumeration where objects are retrieved one by one (hence the name "fast enumeration").
- if there are no objects in the collection, then *`object expression`* is set to `nil` and the loop immediately terminates.
- if there are objects in the collection, then for each object in the collection (in the order they are returned) *`object expression`* is set to the object, then *`statements`* are executed.
- *`statements`* can contain `break` and `continue` commands, which will abort the iteration or skip to the next loop iteration as expected.
- when the iteration ends because there are no more objects to iterate over, *`object expression`* is set to `nil`. This allows you to determine whether the iteration finished because a `break` command was used (in which case *`object expression`* will remain set to the last object that was iterated over) or because it iterated over all the objects (in which case *`object expression`* will be set to `nil`).
- *`statements`* must not make any changes to the collection object; if they do, it is a hard error and the fast enumeration terminates by invoking `objc_enumerationMutation`, a runtime function that normally aborts the program but which can be customized by Foundation libraries via `objc_set_mutation_handler` to do something different, such as raising an exception.

9.9.4 Fast Enumeration Protocol

If you want your own collection object to be usable with fast enumeration, you need to have it implement the method

```
- (unsigned long) countByEnumeratingWithState: (NSFastEnumerationState *)state
                                      objects: (id *)objects
                                        count: (unsigned long)len;
```

where `NSFastEnumerationState` must be defined in your code as follows:

```
typedef struct
{
  unsigned long state;
  id            *itemsPtr;
  unsigned long *mutationsPtr;
  unsigned long extra[5];
} NSFastEnumerationState;
```

If no `NSFastEnumerationState` is defined in your code, the compiler will automatically replace `NSFastEnumerationState *` with `struct __objcFastEnumerationState *`, where that type is silently defined by the compiler in an identical way. This can be confusing and we recommend that you define `NSFastEnumerationState` (as shown above) instead.

The method is called repeatedly during a fast enumeration to retrieve batches of objects. Each invocation of the method should retrieve the next batch of objects.

The return value of the method is the number of objects in the current batch; this should not exceed `len`, which is the maximum size of a batch as requested by the caller. The batch itself is returned in the `itemsPtr` field of the `NSFastEnumerationState` struct.

To help with returning the objects, the `objects` array is a C array preallocated by the caller (on the stack) of size `len`. In many cases you can put the objects you want to return in that `objects` array, then do `itemsPtr = objects`. But you don't have to; if your collection already has the objects to return in some form of C array, it could return them from there instead.

The `state` and `extra` fields of the `NSFastEnumerationState` structure allows your collection object to keep track of the state of the enumeration. In a simple array implementation, `state` may keep track of the index of the last object that was returned, and `extra` may be unused.

The `mutationsPtr` field of the `NSFastEnumerationState` is used to keep track of mutations. It should point to a number; before working on each object, the fast enumeration loop will check that this number has not changed. If it has, a mutation has happened and the fast enumeration will abort. So, `mutationsPtr` could be set to point to some sort of version number of your collection, which is increased by one every time there is a change (for example when an object is added or removed). Or, if you are content with less strict mutation checks, it could point to the number of objects in your collection or some other value that can be checked to perform an approximate check that the collection has not been mutated.

Finally, note how we declared the `len` argument and the return value to be of type `unsigned long`. They could also be declared to be of type `unsigned int` and everything would still work.

9.10 Messaging with the GNU Objective-C Runtime

This section is specific for the GNU Objective-C runtime. If you are using a different runtime, you can skip it.

The implementation of messaging in the GNU Objective-C runtime is designed to be portable, and so is based on standard C.

Sending a message in the GNU Objective-C runtime is composed of two separate steps. First, there is a call to the lookup function, `objc_msg_lookup ()` (or, in the case of messages to super, `objc_msg_lookup_super ()`). This runtime function takes as argument the receiver and the selector of the method to be called; it returns the `IMP`, that is a pointer to the function implementing the method. The second step of method invocation consists of casting this pointer function to the appropriate function pointer type, and calling the function pointed to it with the right arguments.

For example, when the compiler encounters a method invocation such as `[object init]`, it compiles it into a call to `objc_msg_lookup (object, @selector(init))` followed by a cast of the returned value to the appropriate function pointer type, and then it calls it.

9.10.1 Dynamically Registering Methods

If `objc_msg_lookup()` does not find a suitable method implementation, because the receiver does not implement the required method, it tries to see if the class can dynamically register the method.

To do so, the runtime checks if the class of the receiver implements the method

```
+ (BOOL) resolveInstanceMethod: (SEL)selector;
```

in the case of an instance method, or

```
+ (BOOL) resolveClassMethod: (SEL)selector;
```

in the case of a class method. If the class implements it, the runtime invokes it, passing as argument the selector of the original method, and if it returns `YES`, the runtime tries the lookup again, which could now succeed if a matching method was added dynamically by `+resolveInstanceMethod:` or `+resolveClassMethod:`.

This allows classes to dynamically register methods (by adding them to the class using `class_addMethod`) when they are first called. To do so, a class should implement `+resolveInstanceMethod:` (or, depending on the case, `+resolveClassMethod:`) and have it recognize the selectors of methods that can be registered dynamically at runtime, register them, and return `YES`. It should return `NO` for methods that it does not dynamically registered at runtime.

If `+resolveInstanceMethod:` (or `+resolveClassMethod:`) is not implemented or returns `NO`, the runtime then tries the forwarding hook.

Support for `+resolveInstanceMethod:` and `resolveClassMethod:` was added to the GNU Objective-C runtime in GCC version 4.6.

9.10.2 Forwarding Hook

The GNU Objective-C runtime provides a hook, called `__objc_msg_forward2`, which is called by `objc_msg_lookup()` when it cannot find a method implementation in the runtime tables and after calling `+resolveInstanceMethod:` and `+resolveClassMethod:` has been attempted and did not succeed in dynamically registering the method.

To configure the hook, you set the global variable `__objc_msg_forward2` to a function with the same argument and return types of `objc_msg_lookup()`. When `objc_msg_lookup()` cannot find a method implementation, it invokes the hook function you provided to get a method implementation to return. So, in practice `__objc_msg_forward2` allows you to extend `objc_msg_lookup()` by adding some custom code that is called to do a further lookup when no standard method implementation can be found using the normal lookup.

This hook is generally reserved for "Foundation" libraries such as GNUstep Base, which use it to implement their high-level method forwarding API, typically based around the `forwardInvocation:` method. So, unless you are implementing your own "Foundation" library, you should not set this hook.

In a typical forwarding implementation, the `__objc_msg_forward2` hook function determines the argument and return type of the method that is being looked up, and then creates a function that takes these arguments and has that return type, and returns it to the caller. Creating this function is non-trivial and is typically performed using a dedicated library such as `libffi`.

The forwarding method implementation thus created is returned by `objc_msg_lookup()` and is executed as if it was a normal method implementation. When the forwarding method implementation is called, it is usually expected to pack all arguments into some sort of object (typically, an `NSInvocation` in a "Foundation" library), and hand it over to the programmer (`forwardInvocation:`) who is then allowed to manipulate the method invocation using a high-level API provided by the "Foundation" library. For example, the programmer may want to examine the method invocation arguments and name and potentially change them before forwarding the method invocation to one or more local objects (`performInvocation:`) or even to remote objects (by using Distributed Objects or some other mechanism). When all this completes, the return value is passed back and must be returned correctly to the original caller.

Note that the GNU Objective-C runtime currently provides no support for method forwarding or method invocations other than the `__objc_msg_forward2` hook.

If the forwarding hook does not exist or returns `NULL`, the runtime currently attempts forwarding using an older, deprecated API, and if that fails, it aborts the program. In future versions of the GNU Objective-C runtime, the runtime will immediately abort.

10 Binary Compatibility

Binary compatibility encompasses several related concepts:

application binary interface (ABI)
: The set of runtime conventions followed by all of the tools that deal with binary representations of a program, including compilers, assemblers, linkers, and language runtime support. Some ABIs are formal with a written specification, possibly designed by multiple interested parties. Others are simply the way things are actually done by a particular set of tools.

ABI conformance
: A compiler conforms to an ABI if it generates code that follows all of the specifications enumerated by that ABI. A library conforms to an ABI if it is implemented according to that ABI. An application conforms to an ABI if it is built using tools that conform to that ABI and does not contain source code that specifically changes behavior specified by the ABI.

calling conventions
: Calling conventions are a subset of an ABI that specify of how arguments are passed and function results are returned.

interoperability
: Different sets of tools are interoperable if they generate files that can be used in the same program. The set of tools includes compilers, assemblers, linkers, libraries, header files, startup files, and debuggers. Binaries produced by different sets of tools are not interoperable unless they implement the same ABI. This applies to different versions of the same tools as well as tools from different vendors.

intercallability
: Whether a function in a binary built by one set of tools can call a function in a binary built by a different set of tools is a subset of interoperability.

implementation-defined features
: Language standards include lists of implementation-defined features whose behavior can vary from one implementation to another. Some of these features are normally covered by a platform's ABI and others are not. The features that are not covered by an ABI generally affect how a program behaves, but not intercallability.

compatibility
: Conformance to the same ABI and the same behavior of implementation-defined features are both relevant for compatibility.

The application binary interface implemented by a C or C++ compiler affects code generation and runtime support for:

- size and alignment of data types
- layout of structured types
- calling conventions

- register usage conventions
- interfaces for runtime arithmetic support
- object file formats

In addition, the application binary interface implemented by a C++ compiler affects code generation and runtime support for:

- name mangling
- exception handling
- invoking constructors and destructors
- layout, alignment, and padding of classes
- layout and alignment of virtual tables

Some GCC compilation options cause the compiler to generate code that does not conform to the platform's default ABI. Other options cause different program behavior for implementation-defined features that are not covered by an ABI. These options are provided for consistency with other compilers that do not follow the platform's default ABI or the usual behavior of implementation-defined features for the platform. Be very careful about using such options.

Most platforms have a well-defined ABI that covers C code, but ABIs that cover C++ functionality are not yet common.

Starting with GCC 3.2, GCC binary conventions for C++ are based on a written, vendor-neutral C++ ABI that was designed to be specific to 64-bit Itanium but also includes generic specifications that apply to any platform. This C++ ABI is also implemented by other compiler vendors on some platforms, notably GNU/Linux and BSD systems. We have tried hard to provide a stable ABI that will be compatible with future GCC releases, but it is possible that we will encounter problems that make this difficult. Such problems could include different interpretations of the C++ ABI by different vendors, bugs in the ABI, or bugs in the implementation of the ABI in different compilers. GCC's `-Wabi` switch warns when G++ generates code that is probably not compatible with the C++ ABI.

The C++ library used with a C++ compiler includes the Standard C++ Library, with functionality defined in the C++ Standard, plus language runtime support. The runtime support is included in a C++ ABI, but there is no formal ABI for the Standard C++ Library. Two implementations of that library are interoperable if one follows the de-facto ABI of the other and if they are both built with the same compiler, or with compilers that conform to the same ABI for C++ compiler and runtime support.

When G++ and another C++ compiler conform to the same C++ ABI, but the implementations of the Standard C++ Library that they normally use do not follow the same ABI for the Standard C++ Library, object files built with those compilers can be used in the same program only if they use the same C++ library. This requires specifying the location of the C++ library header files when invoking the compiler whose usual library is not being used. The location of GCC's C++ header files depends on how the GCC build was configured, but can be seen by using the G++ `-v` option. With default configuration options for G++ 3.3 the compile line for a different C++ compiler needs to include

```
-Igcc_install_directory/include/c++/3.3
```

Similarly, compiling code with G++ that must use a C++ library other than the GNU C++ library requires specifying the location of the header files for that other library.

The most straightforward way to link a program to use a particular C++ library is to use a C++ driver that specifies that C++ library by default. The `g++` driver, for example, tells the linker where to find GCC's C++ library (`libstdc++`) plus the other libraries and startup files it needs, in the proper order.

If a program must use a different C++ library and it's not possible to do the final link using a C++ driver that uses that library by default, it is necessary to tell `g++` the location and name of that library. It might also be necessary to specify different startup files and other runtime support libraries, and to suppress the use of GCC's support libraries with one or more of the options `-nostdlib`, `-nostartfiles`, and `-nodefaultlibs`.

11 gcov—a Test Coverage Program

`gcov` is a tool you can use in conjunction with GCC to test code coverage in your programs.

11.1 Introduction to gcov

`gcov` is a test coverage program. Use it in concert with GCC to analyze your programs to help create more efficient, faster running code and to discover untested parts of your program. You can use `gcov` as a profiling tool to help discover where your optimization efforts will best affect your code. You can also use `gcov` along with the other profiling tool, `gprof`, to assess which parts of your code use the greatest amount of computing time.

Profiling tools help you analyze your code's performance. Using a profiler such as `gcov` or `gprof`, you can find out some basic performance statistics, such as:

- how often each line of code executes
- what lines of code are actually executed
- how much computing time each section of code uses

Once you know these things about how your code works when compiled, you can look at each module to see which modules should be optimized. `gcov` helps you determine where to work on optimization.

Software developers also use coverage testing in concert with testsuites, to make sure software is actually good enough for a release. Testsuites can verify that a program works as expected; a coverage program tests to see how much of the program is exercised by the testsuite. Developers can then determine what kinds of test cases need to be added to the testsuites to create both better testing and a better final product.

You should compile your code without optimization if you plan to use `gcov` because the optimization, by combining some lines of code into one function, may not give you as much information as you need to look for 'hot spots' where the code is using a great deal of computer time. Likewise, because `gcov` accumulates statistics by line (at the lowest resolution), it works best with a programming style that places only one statement on each line. If you use complicated macros that expand to loops or to other control structures, the statistics are less helpful—they only report on the line where the macro call appears. If your complex macros behave like functions, you can replace them with inline functions to solve this problem.

`gcov` creates a logfile called *`sourcefile`*`.gcov` which indicates how many times each line of a source file *`sourcefile`*`.c` has executed. You can use these logfiles along with `gprof` to aid in fine-tuning the performance of your programs. `gprof` gives timing information you can use along with the information you get from `gcov`.

`gcov` works only on code compiled with GCC. It is not compatible with any other profiling or test coverage mechanism.

11.2 Invoking gcov

```
gcov [options] files
```

`gcov` accepts the following options:

`-a`
`--all-blocks`
Write individual execution counts for every basic block. Normally gcov outputs execution counts only for the main blocks of a line. With this option you can determine if blocks within a single line are not being executed.

`-b`
`--branch-probabilities`
Write branch frequencies to the output file, and write branch summary info to the standard output. This option allows you to see how often each branch in your program was taken. Unconditional branches will not be shown, unless the `-u` option is given.

`-c`
`--branch-counts`
Write branch frequencies as the number of branches taken, rather than the percentage of branches taken.

`-g`
`--conditions`
Write condition coverage to the output file, and write condition summary info to the standard output. This option allows you to see if the conditions in your program at least once had an independent effect on the outcome of the boolean expression (modified condition/decision coverage). This requires you to compile the source with `-fcondition-coverage`.

`-e`
`--prime-paths`
Write path coverage to the output file, and write path summary info to the standard output. This option allows you to see how many prime paths were taken at least once. A path is a sequence of basic blocks. A path is simple if it has no repeated blocks (no loops) except maybe the first and last block, and prime if it is a simple path of maximal length. For the regular output this option only includes the number of paths covered. For more fine grained information on paths you can use `--prime-paths-lines` or `--prime-paths-source`. With `--json-format` all path details are included in the output. This requires you to compile the source with `-fpath-coverage`.

`--prime-paths-lines [=`*`type`*`]`
Write path coverage to the output file, and write path summary info to the standard output. This option allows you to see how many prime paths were taken at least once, and dense report on the covered or uncovered paths and how to cover them. This mode is useful for automated reporting and progress tracking. *type* may be omitted, or one of:

- *uncovered* - Include the uncovered (not taken) paths. This is the default.
- *covered* - Include the covered (taken) paths.
- *both* - Include all paths. This is equivalent to using both *covered* and *uncovered*.

This is an example of `--prime-paths-lines` output:

```
paths covered 12 of 15
path  2 not covered: lines 8 8(false) 11(true) 11 13(true) 13(true) 14 17
path  3 not covered: lines 8 8(false) 11(true) 11 13(true) 13(false) 16 17
path  4 not covered: lines 8 8(false) 11(true) 11 13(false) 16 17
```

This means to cover path 2 you must run lines 8, 11, 13, 14, and 17, evaluting the decision at 8 false and the decisions at 11 and 13 to `false`.

`--prime-paths-source [=`*type*`]`

Write path coverage to the output file, and write path summary info to the standard output. This option allows you to see how many prime paths were taken at least once, and detailed report on the uncovered paths an how to cover them. This mode is useful for understanding paths and interactions between sections of your program. *type* may be omitted, or one of:

- *uncovered* - Include the uncovered (not taken) paths. This is the default.
- *covered* - Include the covered (taken) paths.
- *both* - Include all paths. This is equivalent to using both *covered* and *uncovered*.

This is an example of `--prime-paths-source` output:

```
path 10 not covered:
BB  3:           8:  for (i = 0; i < 10; i++)
BB  3:           9:    total += i;
BB  4: (false)   8:  for (i = 0; i < 10; i++)
BB  5: (true)   11:  int v = total > 100 ? 1 : 2;
BB  6:          11:  int v = total > 100 ? 1 : 2;
BB  8: (false)  13:  if (total != 45 && v == 1)
BB 11:          16:    printf ("Success\n");
BB 12:          17:  return 0;
```

The first (BB) column is the sequence of basic blocks (see `-w`). The middle column (true/false) is the decision for that line. The third column is the line number. The fourth column is the line itself. These lines must be run in this order to cover path 10.

`-d`
`--display-progress`

Display the progress on the standard output.

`-f`
`--function-summaries`

Output summaries for each function in addition to the file level summary.

`--include` *regex*

Include functions matching *regex*. This option makes `gcov` only report on functions that match the extended regular expression *regex*. This flag can be combined with `--exclude`. If a function matches both includes and excludes, the last include/exclude applies. By default `gcov` reports on all functions, but if a `--include` is used then only functions matching the include will be reported.

`--exclude` *regex*

Exclude functions matching *regex*. This option makes `gcov` not report on functions that match the extended regular expression *regex*. This flag can be combined with `--include`. If a function matches both includes and excludes, the last include/exclude applies. By default `gcov` reports on all functions, and if `--exclude` is used then functions matching it will be omitted.

`-h`
`--help` Display help about using `gcov` (on the standard output), and exit without doing any further processing.

`-j`
`--json-format`

Output gcov file in an easy-to-parse JSON intermediate format which does not require source code for generation. The JSON file is compressed with gzip compression algorithm and the files have `.gcov.json.gz` extension.

Structure of the JSON is following:

```
{
  "current_working_directory": "foo/bar",
  "data_file": "a.out",
  "format_version": "2",
  "gcc_version": "11.1.1 20210510"
  "files": ["$file"]
}
```

Fields of the root element have following semantics:

- *current_working_directory*: working directory where a compilation unit was compiled
- *data_file*: name of the data file (GCDA)
- *format_version*: semantic version of the format

  Changes in version *2*:

  - *calls*: information about function calls is added
- *gcc_version*: version of the GCC compiler

Each *file* has the following form:

```
{
  "file": "a.c",
  "functions": ["$function"],
  "lines": ["$line"]
}
```

Fields of the *file* element have following semantics:

- *file_name*: name of the source file

Each *function* has the following form:

```
{
  "blocks": 2,
  "blocks_executed": 2,
  "demangled_name": "foo",
  "end_column": 1,
  "end_line": 4,
  "execution_count": 1,
  "name": "foo",
  "start_column": 5,
  "start_line": 1
}
```

Fields of the *function* element have following semantics:

- *blocks*: number of blocks that are in the function
- *blocks_executed*: number of executed blocks of the function
- *demangled_name*: demangled name of the function
- *end_column*: column in the source file where the function ends
- *end_line*: line in the source file where the function ends
- *execution_count*: number of executions of the function
- *name*: name of the function
- *start_column*: column in the source file where the function begins
- *start_line*: line in the source file where the function begins

Note that line numbers and column numbers number from 1. In the current implementation, *start_line* and *start_column* do not include any template parameters and the leading return type but that this is likely to be fixed in the future.

Each *line* has the following form:

```
{
  "block_ids": ["$block_id"],
  "branches": ["$branch"],
  "calls": ["$call"],
  "count": 2,
  "conditions": ["$condition"],
  "line_number": 15,
  "unexecuted_block": false,
  "function_name": "foo",
}
```

Branches and calls are present only with *-b* option. Fields of the *line* element have following semantics:

- *block_ids*: IDs of basic blocks that belong to the line
- *count*: number of executions of the line
- *line_number*: line number
- *unexecuted_block*: flag whether the line contains an unexecuted block (not all statements on the line are executed)
- *function_name*: a name of a function this *line* belongs to (for a line with an inlined statements can be not set)

Each *branch* has the following form:

```
{
  "count": 11,
  "destination_block_id": 17,
  "fallthrough": true,
  "source_block_id": 13,
  "throw": false
}
```

Fields of the *branch* element have following semantics:

- *count*: number of executions of the branch
- *fallthrough*: true when the branch is a fall through branch

- *throw*: true when the branch is an exceptional branch
- *isource_block_id*: ID of the basic block where this branch happens
- *destination_block_id*: ID of the basic block this branch jumps to

Each *call* has the following form:

```
{
  "destination_block_id": 1,
  "returned": 11,
  "source_block_id": 13
}
```

Fields of the *call* element have following semantics:

- *returned*: number of times a function call returned (call count is equal to *line::count*)
- *isource_block_id*: ID of the basic block where this call happens
- *destination_block_id*: ID of the basic block this calls continues after return

Each *condition* has the following form:

```
{
  "count": 4,
  "covered": 2,
  "not_covered_false": [],
  "not_covered_true": [0, 1],
}
```

Fields of the *condition* element have following semantics:

- *count*: number of condition outcomes in this expression
- *covered*: number of covered condition outcomes in this expression
- *not_covered_true*: terms, by index, not seen as true in this expression
- *not_covered_false*: terms, by index, not seen as false in this expression

`-H`
`--human-readable`
: Write counts in human readable format (like 24.6k).

`-k`
`--use-colors`
: Use colors for lines of code that have zero coverage. We use red color for non-exceptional lines and cyan for exceptional. Same colors are used for basic blocks with `-a` option.

`-l`
`--long-file-names`
: Create long file names for included source files. For example, if the header file `x.h` contains code, and was included in the file `a.c`, then running `gcov` on the file `a.c` will produce an output file called `a.c##x.h.gcov` instead of `x.h.gcov`. This can be useful if `x.h` is included in multiple source files and you want to see the individual contributions. If you use the '`-p`' option, both the including and included file names will be complete path names.

`-m`
`--demangled-names`
: Display demangled function names in output. The default is to show mangled function names.

`-M`
`--filter-on-demangled`
: Make `--include` and `--exclude` match demangled names. This does only affects the matching and does not imply `--demangled-names`, but it can safely be combined with it.

`-n`
`--no-output`
: Do not create the `gcov` output file.

`-o` *directory|file*
`--object-directory` *directory*
`--object-file` *file*
: Specify either the directory containing the gcov data files, or the object path name. The `.gcno`, and `.gcda` data files are searched for using this option. If a directory is specified, the data files are in that directory and named after the input file name, without its extension. If a file is specified here, the data files are named after that file, without its extension.

`-p`
`--preserve-paths`
: Preserve complete path information in the names of generated `.gcov` files. Without this option, just the filename component is used. With this option, all directories are used, with '`/`' characters translated to '`#`' characters, `.` directory components removed and unremoveable `..` components renamed to '`^`'. This is useful if sourcefiles are in several different directories.

`-q`
`--use-hotness-colors`
: Emit perf-like colored output for hot lines. Legend of the color scale is printed at the very beginning of the output file.

`-r`
`--relative-only`
: Only output information about source files with a relative pathname (after source prefix elision). Absolute paths are usually system header files and coverage of any inline functions therein is normally uninteresting.

`-s` *directory*
`--source-prefix` *directory*
: A prefix for source file names to remove when generating the output coverage files. This option is useful when building in a separate directory, and the pathname to the source directory is not wanted when determining the output file names. Note that this prefix detection is applied before determining whether the source file is absolute.

-t
--stdout Output to standard output instead of output files.

-u
--unconditional-branches
When branch probabilities are given, include those of unconditional branches. Unconditional branches are normally not interesting.

-v
--version
Display the gcov version number (on the standard output), and exit without doing any further processing.

-w
--verbose
Print verbose informations related to basic blocks and arcs.

-x
--hash-filenames
When using *–preserve-paths*, gcov uses the full pathname of the source files to create an output filename. This can lead to long filenames that can overflow filesystem limits. This option creates names of the form *source-file*##*md5*.gcov, where the *source-file* component is the final filename part and the *md5* component is calculated from the full mangled name that would have been used otherwise. The option is an alternative to the *–preserve-paths* on systems which have a filesystem limit.

gcov should be run with the current directory the same as that when you invoked the compiler. Otherwise it will not be able to locate the source files. gcov produces files called *mangledname*.gcov in the current directory. These contain the coverage information of the source file they correspond to. One .gcov file is produced for each source (or header) file containing code, which was compiled to produce the data files. The *mangledname* part of the output file name is usually simply the source file name, but can be something more complicated if the '-l' or '-p' options are given. Refer to those options for details.

If you invoke gcov with multiple input files, the contributions from each input file are summed. Typically you would invoke it with the same list of files as the final link of your executable.

The .gcov files contain the ':' separated fields along with program source code. The format is

```
execution_count:line_number:source line text
```

Additional block information may succeed each line, when requested by command line option. The *execution_count* is '-' for lines containing no code. Unexecuted lines are marked '#####' or '=====', depending on whether they are reachable by non-exceptional paths or only exceptional paths such as C++ exception handlers, respectively. Given the '-a' option, unexecuted blocks are marked '$$$$$' or '%%%%%', depending on whether a basic block is reachable via non-exceptional or exceptional paths. Executed basic blocks having a statement with zero *execution_count* end with '*' character and are colored with magenta color with the -k option. This functionality is not supported in Ada.

Note that GCC can completely remove the bodies of functions that are not needed – for instance if they are inlined everywhere. Such functions are marked with '-', which can be confusing. Use the `-fkeep-inline-functions` and `-fkeep-static-functions` options to retain these functions and allow gcov to properly show their *execution_count*.

Some lines of information at the start have *line_number* of zero. These preamble lines are of the form

```
-:0:tag:value
```

The ordering and number of these preamble lines will be augmented as `gcov` development progresses — do not rely on them remaining unchanged. Use *tag* to locate a particular preamble line.

The additional block information is of the form

```
tag information
```

The *information* is human readable, but designed to be simple enough for machine parsing too.

When printing percentages, 0% and 100% are only printed when the values are *exactly* 0% and 100% respectively. Other values which would conventionally be rounded to 0% or 100% are instead printed as the nearest non-boundary value.

When using `gcov`, you must first compile your program with a special GCC option '`--coverage`'. This tells the compiler to generate additional information needed by gcov (basically a flow graph of the program) and also includes additional code in the object files for generating the extra profiling information needed by gcov. These additional files are placed in the directory where the object file is located.

Running the program will cause profile output to be generated. For each source file compiled with `-fprofile-arcs`, an accompanying `.gcda` file will be placed in the object file directory.

Running `gcov` with your program's source file names as arguments will now produce a listing of the code along with frequency of execution for each line. For example, if your program is called `tmp.cpp`, this is what you see when you use the basic `gcov` facility:

```
$ g++ --coverage tmp.cpp -c
$ g++ --coverage tmp.o
$ a.out
$ gcov tmp.cpp -m
File 'tmp.cpp'
Lines executed:92.86% of 14
Creating 'tmp.cpp.gcov'
```

The file `tmp.cpp.gcov` contains output from `gcov`. Here is a sample:

```
        -:    0:Source:tmp.cpp
        -:    0:Working directory:/home/gcc/testcase
        -:    0:Graph:tmp.gcno
        -:    0:Data:tmp.gcda
        -:    0:Runs:1
        -:    0:Programs:1
        -:    1:#include <stdio.h>
        -:    2:
        -:    3:template<class T>
        -:    4:class Foo
        -:    5:{
        -:    6:  public:
```

```
        1*:    7:  Foo(): b (1000) {}
------------------
Foo<char>::Foo():
    #####:    7:  Foo(): b (1000) {}
------------------
Foo<int>::Foo():
        1:    7:  Foo(): b (1000) {}
------------------
        2*:    8:  void inc () { b++; }
------------------
Foo<char>::inc():
    #####:    8:  void inc () { b++; }
------------------
Foo<int>::inc():
        2:    8:  void inc () { b++; }
------------------
        -:    9:
        -:   10:  private:
        -:   11:  int b;
        -:   12:};
        -:   13:
        -:   14:template class Foo<int>;
        -:   15:template class Foo<char>;
        -:   16:
        -:   17:int
        1:   18:main (void)
        -:   19:{
        -:   20:  int i, total;
        1:   21:  Foo<int> counter;
        -:   22:
        1:   23:  counter.inc();
        1:   24:  counter.inc();
        1:   25:  total = 0;
        -:   26:
       11:   27:  for (i = 0; i < 10; i++)
       10:   28:    total += i;
        -:   29:
       1*:   30:  int v = total > 100 ? 1 : 2;
        -:   31:
        1:   32:  if (total != 45)
    #####:   33:    printf ("Failure\n");
        -:   34:  else
        1:   35:    printf ("Success\n");
        1:   36:  return 0;
        -:   37:}
```

Note that line 7 is shown in the report multiple times. First occurrence presents total number of execution of the line and the next two belong to instances of class Foo constructors. As you can also see, line 30 contains some unexecuted basic blocks and thus execution count has asterisk symbol.

When you use the `-a` option, you will get individual block counts, and the output looks like this:

```
        -:    0:Source:tmp.cpp
        -:    0:Working directory:/home/gcc/testcase
        -:    0:Graph:tmp.gcno
        -:    0:Data:tmp.gcda
        -:    0:Runs:1
```

```
        -:    0:Programs:1
        -:    1:#include <stdio.h>
        -:    2:
        -:    3:template<class T>
        -:    4:class Foo
        -:    5:{
        -:    6:  public:
       1*:    7:  Foo(): b (1000) {}
------------------
Foo<char>::Foo():
    #####:    7:  Foo(): b (1000) {}
------------------
Foo<int>::Foo():
        1:    7:  Foo(): b (1000) {}
------------------
       2*:    8:  void inc () { b++; }
------------------
Foo<char>::inc():
    #####:    8:  void inc () { b++; }
------------------
Foo<int>::inc():
        2:    8:  void inc () { b++; }
------------------
        -:    9:
        -:   10:  private:
        -:   11:  int b;
        -:   12:};
        -:   13:
        -:   14:template class Foo<int>;
        -:   15:template class Foo<char>;
        -:   16:
        -:   17:int
        1:   18:main (void)
        -:   19:{
        -:   20:  int i, total;
        1:   21:  Foo<int> counter;
        1:   21-block  0
        -:   22:
        1:   23:  counter.inc();
        1:   23-block  0
        1:   24:  counter.inc();
        1:   24-block  0
        1:   25:  total = 0;
        -:   26:
       11:   27:  for (i = 0; i < 10; i++)
        1:   27-block  0
       11:   27-block  1
       10:   28:    total += i;
       10:   28-block  0
        -:   29:
       1*:   30:  int v = total > 100 ? 1 : 2;
        1:   30-block  0
    %%%%%:   30-block  1
        1:   30-block  2
        -:   31:
        1:   32:  if (total != 45)
        1:   32-block  0
    #####:   33:    printf ("Failure\n");
```

```
    %%%%%:   33-block  0
        -:   34:  else
        1:   35:    printf ("Success\n");
        1:   35-block  0
        1:   36:  return 0;
        1:   36-block  0
        -:   37:}
```

In this mode, each basic block is only shown on one line – the last line of the block. A multi-line block will only contribute to the execution count of that last line, and other lines will not be shown to contain code, unless previous blocks end on those lines. The total execution count of a line is shown and subsequent lines show the execution counts for individual blocks that end on that line. After each block, the branch and call counts of the block will be shown, if the `-b` option is given.

Because of the way GCC instruments calls, a call count can be shown after a line with no individual blocks. As you can see, line 33 contains a basic block that was not executed.

When you use the `-b` option, your output looks like this:

```
        -:    0:Source:tmp.cpp
        -:    0:Working directory:/home/gcc/testcase
        -:    0:Graph:tmp.gcno
        -:    0:Data:tmp.gcda
        -:    0:Runs:1
        -:    0:Programs:1
        -:    1:#include <stdio.h>
        -:    2:
        -:    3:template<class T>
        -:    4:class Foo
        -:    5:{
        -:    6:  public:
       1*:    7:  Foo(): b (1000) {}
------------------
Foo<char>::Foo():
function Foo<char>::Foo() called 0 returned 0% blocks executed 0%
    #####:    7:  Foo(): b (1000) {}
------------------
Foo<int>::Foo():
function Foo<int>::Foo() called 1 returned 100% blocks executed 100%
        1:    7:  Foo(): b (1000) {}
------------------
       2*:    8:  void inc () { b++; }
------------------
Foo<char>::inc():
function Foo<char>::inc() called 0 returned 0% blocks executed 0%
    #####:    8:  void inc () { b++; }
------------------
Foo<int>::inc():
function Foo<int>::inc() called 2 returned 100% blocks executed 100%
        2:    8:  void inc () { b++; }
------------------
        -:    9:
        -:   10:  private:
        -:   11:  int b;
        -:   12:};
        -:   13:
        -:   14:template class Foo<int>;
        -:   15:template class Foo<char>;
```

```
        -:   16:
        -:   17:int
function main called 1 returned 100% blocks executed 81%
        1:   18:main (void)
        -:   19:{
        -:   20:  int i, total;
        1:   21:  Foo<int> counter;
call    0 returned 100%
branch  1 taken 100% (fallthrough)
branch  2 taken 0% (throw)
        -:   22:
        1:   23:  counter.inc();
call    0 returned 100%
branch  1 taken 100% (fallthrough)
branch  2 taken 0% (throw)
        1:   24:  counter.inc();
call    0 returned 100%
branch  1 taken 100% (fallthrough)
branch  2 taken 0% (throw)
        1:   25:  total = 0;
        -:   26:
       11:   27:  for (i = 0; i < 10; i++)
branch  0 taken 91% (fallthrough)
branch  1 taken 9%
       10:   28:    total += i;
        -:   29:
       1*:   30:  int v = total > 100 ? 1 : 2;
branch  0 taken 0% (fallthrough)
branch  1 taken 100%
        -:   31:
        1:   32:  if (total != 45)
branch  0 taken 0% (fallthrough)
branch  1 taken 100%
    #####:   33:    printf ("Failure\n");
call    0 never executed
branch  1 never executed
branch  2 never executed
        -:   34:  else
        1:   35:    printf ("Success\n");
call    0 returned 100%
branch  1 taken 100% (fallthrough)
branch  2 taken 0% (throw)
        1:   36:  return 0;
        -:   37:}
```

For each function, a line is printed showing how many times the function is called, how many times it returns and what percentage of the function's blocks were executed.

For each basic block, a line is printed after the last line of the basic block describing the branch or call that ends the basic block. There can be multiple branches and calls listed for a single source line if there are multiple basic blocks that end on that line. In this case, the branches and calls are each given a number. There is no simple way to map these branches and calls back to source constructs. In general, though, the lowest numbered branch or call will correspond to the leftmost construct on the source line.

For a branch, if it was executed at least once, then a percentage indicating the number of times the branch was taken divided by the number of times the branch was executed will be printed. Otherwise, the message "never executed" is printed.

For a call, if it was executed at least once, then a percentage indicating the number of times the call returned divided by the number of times the call was executed will be printed. This will usually be 100%, but may be less for functions that call `exit` or `longjmp`, and thus may not return every time they are called.

When you use the `-g` option, your output looks like this:

```
$ gcov -t -m -g tmp
        -:    0:Source:tmp.cpp
        -:    0:Graph:tmp.gcno
        -:    0:Data:tmp.gcda
        -:    0:Runs:1
        -:    1:#include <stdio.h>
        -:    2:
        -:    3:int
        1:    4:main (void)
        -:    5:{
        -:    6:  int i, total;
        1:    7:  total = 0;
        -:    8:
       11:    9:  for (i = 0; i < 10; i++)
condition outcomes covered 2/2
       10:   10:    total += i;
        -:   11:
       1*:   12:  int v = total > 100 ? 1 : 2;
condition outcomes covered 1/2
condition  0 not covered (true)
        -:   13:
       1*:   14:  if (total != 45 && v == 1)
condition outcomes covered 1/4
condition  0 not covered (true)
condition  1 not covered (true false)
    #####:   15:    printf ("Failure\n");
        -:   16:  else
        1:   17:    printf ("Success\n");
        1:   18:  return 0;
        -:   19:}
```

For every condition the number of taken and total outcomes are printed, and if there are uncovered outcomes a line will be printed for each condition showing the uncovered outcome in parentheses. Conditions are identified by their index – index 0 is the left-most condition. In `a || (b && c)`, *a* is condition 0, *b* condition 1, and *c* condition 2.

An outcome is considered covered if it has an independent effect on the decision, also known as masking MC/DC (Modified Condition/Decision Coverage). In this example the decision evaluates to true and *a* is evaluated, but not covered. This is because *a* cannot affect the decision independently – both *a* and *b* must change value for the decision to change.

```
$ gcov -t -m -g tmp
        -:    0:Source:tmp.c
        -:    0:Graph:tmp.gcno
        -:    0:Data:tmp.gcda
        -:    0:Runs:1
        -:    1:#include <stdio.h>
        -:    2:
        1:    3:int main()
        -:    4:{
        1:    5:  int a = 1;
```

```
            1:    6:  int b = 0;
            -:    7:
            1:    8:  if (a && b)
condition outcomes covered 1/4
condition  0 not covered (true false)
condition  1 not covered (true)
        #####:    9:    printf ("Success!\n");
            -:   10:  else
            1:   11:    printf ("Failure!\n");
            -:   12:}
```

When you compile with `--coverage -fpath-coverage` and use the option `-e` your output looks like this:

```
$ gcov -t -e tmp
        -:    0:Source:tmp.cpp
        -:    0:Graph:tmp.gcno
        -:    0:Data:tmp.gcda
        -:    0:Runs:1
        -:    1:#include <stdio.h>
        -:    2:
paths covered 4 of 15
        1:    3:int main ()
        -:    4:{
        -:    5:  int i, total;
        1:    6:  total = 0;
        -:    7:
       11:    8:  for (i = 0; i < 10; i++)
       10:    9:    total += i;
        -:   10:
       1*:   11:  int v = total > 100 ? 1 : 2;
        -:   12:
       1*:   13:  if (total != 45 && v == 1)
    #####:   14:    printf ("Failure\n");
        -:   15:  else
        1:   16:    printf ("Success\n");
        1:   17:  return 0;
        -:   18:}
```

This output is useful to figure out roughly where coverage is missing and testing how different inputs change the coverage. The `--prime-paths-source` is a useful tool for understanding paths.

```
$ gcov -t --prime-paths-source tmp
        -:    0:Source:tmp.cpp
        -:    0:Graph:tmp.gcno
        -:    0:Data:tmp.gcda
        -:    0:Runs:1
        -:    1:#include <stdio.h>
        -:    2:
paths covered 4 of 15
path 1:
BB  2:           3:int main ()
BB  2:           6:  total = 0;
BB  2:           8:  for (i = 0; i < 10; i++)
BB  4: (false)   8:  for (i = 0; i < 10; i++)
BB  5: (true)   11:  int v = total > 100 ? 1 : 2;
BB  6:          11:  int v = total > 100 ? 1 : 2;
BB  8: (true)   13:  if (total != 45 && v == 1)
BB  9: (true)   13:  if (total != 45 && v == 1)
```

```
BB 10:          14:    printf ("Failure\n");
BB 12:          17:  return 0;
```

In this mode, gcov will print details on the missing paths. The first column lists the sequence of basic blocks (BB). The second column is the decision to take at that line if there is one. The final columns are the line number and the line itself. This is useful for understanding the paths, in particular those that are hard to cover or even unreachable. Lines may be repeated, for example the `for` loop, if the same line is a part of multiple basic blocks. This mode is intended for humans and good at understanding what code is exercised under testing or for given inputs. This output is quite verbose, and for focusing on specific functions it can be combined with the filters `--include` and `--exclude`.

A denser output is available with `--prime-paths-lines`, which looks like this:

```
        -:    0:Source:tmp.cpp
        -:    0:Graph:tmp.gcno
        -:    0:Data:tmp.gcda
        -:    0:Runs:1
        -:    1:#include <stdio.h>
        -:    2:
paths covered 4 of 15
path  1 not covered: lines 8 8(false) 11(true) 11 13(true) 13(true) 14 17
path  2 not covered: lines 8 8(false) 11(true) 11 13(true) 13(false) 16 17
path  3 not covered: lines 8 8(false) 11(true) 11 13(false) 16 17
path  4 not covered: lines 8 8(false) 11(false) 11 13(true) 13(true) 14 17
path  5 not covered: lines 8 8(false) 11(false) 11 13(true) 13(false) 16 17
path  6 not covered: lines 8 8(false) 11(false) 11 13(false) 16 17
path  8 not covered: lines 9 8(false) 11(true) 11 13(true) 13(true) 14 17
path  9 not covered: lines 9 8(false) 11(true) 11 13(true) 13(false) 16 17
path 10 not covered: lines 9 8(false) 11(true) 11 13(false) 16 17
path 11 not covered: lines 9 8(false) 11(false) 11 13(true) 13(true) 14 17
path 12 not covered: lines 9 8(false) 11(false) 11 13(true) 13(false) 16 17
        1:    3:int main ()
        -:    4:{
```

In this mode, every missing path is expanded using the lines and decisions like `--prime-paths-source` but printed on a single line. This mode provides a good overview over the paths and for tracking how different tests and inputs exercises the code.

The execution counts are cumulative. If the example program were executed again without removing the `.gcda` file, the count for the number of times each line in the source was executed would be added to the results of the previous run(s). This is potentially useful in several ways. For example, it could be used to accumulate data over a number of program runs as part of a test verification suite, or to provide more accurate long-term information over a large number of program runs.

The data in the `.gcda` files is saved immediately before the program exits. For each source file compiled with `-fprofile-arcs`, the profiling code first attempts to read in an existing `.gcda` file; if the file doesn't match the executable (differing number of basic block counts) it will ignore the contents of the file. It then adds in the new execution counts and finally writes the data to the file.

You can report on a subset of functions by using `--include` and `--exclude`. This is very useful when combined with `--stdout` trying to understand behavior and coverage for a particular function by running a test, looking at `gcov` output, testing another input, and running `gcov` again.

```
$ gcov -m --stdout --include inc tmp
```

```
        -:    0:Source:tmp.cpp
        -:    0:Graph:tmp.gcno
        -:    0:Data:tmp.gcda
        -:    0:Runs:1
       2*:    8:  void inc () { b++; }
------------------
Foo<char>::inc():
    #####:    8:  void inc () { b++; }
------------------
Foo<int>::inc():
        2:    8:  void inc () { b++; }
------------------
```

`gcov` will match on mangled names by default, which you can control with the `-M` flag. Note that matching and reporting are independent, so you can match on mangled names while printing demangled names, and vice versa. To report on the `int` instantiation of `Foo` matching on mangled and demangled names:

```
$ gcov -t -m -M tmp --include 'Foo<int>'
        -:    0:Source:tmp.cpp
        -:    0:Graph:tmp.gcno
        -:    0:Data:tmp.gcda
        -:    0:Runs:1
        1:    7:  Foo(): b (1000) {}
        2:    8:  void inc () { b++; }
$ gcov -t -m tmp --include 'FooIi'
        -:    0:Source:tmp.cpp
        -:    0:Graph:tmp.gcno
        -:    0:Data:tmp.gcda
        -:    0:Runs:1
        1:    7:  Foo(): b (1000) {}
        2:    8:  void inc () { b++; }
```

The arguments to `--include` and `--exclude` are extended regular expressions (like `grep -E`), so the pattern `in.?` matches both `inc` and `main`. If used with `-M` then all `int` instantiations of `Foo` would match too. `--include` and `--exclude` can be used multiple times, and if a name matches multiple filters it is the last one to match which takes preference. For example, to match `main` and the `int` instatiation of `inc`, while omitting the `Foo` constructor:

```
$ gcov -t -m -M --include in --exclude Foo --include '<int>::inc' tmp
        -:    0:Source:tmp.cpp
        -:    0:Graph:tmp.gcno
        -:    0:Data:tmp.gcda
        -:    0:Runs:1
        2:    8:  void inc () { b++; }
        1:   18:main (void)
        -:   19:{
        -:   20:  int i, total;
        1:   21:  Foo<int> counter;
        -:   22:
        1:   23:  counter.inc();
        1:   24:  counter.inc();
        1:   25:  total = 0;
        -:   26:
       11:   27:  for (i = 0; i < 10; i++)
       10:   28:    total += i;
        -:   29:
       1*:   30:  int v = total > 100 ? 1 : 2;
        -:   31:
```

```
        1:   32:  if (total != 45)
    #####:   33:    printf ("Failure\n");
        -:   34:  else
        1:   35:    printf ("Success\n");
        1:   36:  return 0;
```

11.3 Using gcov with GCC Optimization

If you plan to use `gcov` to help optimize your code, you must first compile your program with a special GCC option '`--coverage`'. Aside from that, you can use any other GCC options; but if you want to prove that every single line in your program was executed, you should not compile with optimization at the same time. On some machines the optimizer can eliminate some simple code lines by combining them with other lines. For example, code like this:

```
if (a != b)
  c = 1;
else
  c = 0;
```

can be compiled into one instruction on some machines. In this case, there is no way for `gcov` to calculate separate execution counts for each line because there isn't separate code for each line. Hence the `gcov` output looks like this if you compiled the program with optimization:

```
      100:   12:if (a != b)
      100:   13:  c = 1;
      100:   14:else
      100:   15:  c = 0;
```

The output shows that this block of code, combined by optimization, executed 100 times. In one sense this result is correct, because there was only one instruction representing all four of these lines. However, the output does not indicate how many times the result was 0 and how many times the result was 1.

Inlineable functions can create unexpected line counts. Line counts are shown for the source code of the inlineable function, but what is shown depends on where the function is inlined, or if it is not inlined at all.

If the function is not inlined, the compiler must emit an out of line copy of the function, in any object file that needs it. If `fileA.o` and `fileB.o` both contain out of line bodies of a particular inlineable function, they will also both contain coverage counts for that function. When `fileA.o` and `fileB.o` are linked together, the linker will, on many systems, select one of those out of line bodies for all calls to that function, and remove or ignore the other. Unfortunately, it will not remove the coverage counters for the unused function body. Hence when instrumented, all but one use of that function will show zero counts.

If the function is inlined in several places, the block structure in each location might not be the same. For instance, a condition might now be calculable at compile time in some instances. Because the coverage of all the uses of the inline function will be shown for the same source lines, the line counts themselves might seem inconsistent.

Long-running applications can use the `__gcov_reset` and `__gcov_dump` facilities to restrict profile collection to the program region of interest. Calling `__gcov_reset(void)` will clear all run-time profile counters to zero, and calling `__gcov_dump(void)` will cause the profile information collected at that point to be dumped to `.gcda` output files. Instrumented applications use a static destructor with priority 99 to invoke the `__gcov_dump` function. Thus `__gcov_dump` is executed after all user defined static destructors, as well as handlers registered with `atexit`.

If an executable loads a dynamic shared object via dlopen functionality, `-Wl,--dynamic-list-data` is needed to dump all profile data.

Profiling run-time library reports various errors related to profile manipulation and profile saving. Errors are printed into standard error output or 'GCOV_ERROR_FILE' file, if environment variable is used. In order to terminate immediately after an errors occurs set 'GCOV_EXIT_AT_ERROR' environment variable. That can help users to find profile clashing which leads to a misleading profile.

11.4 Brief Description of gcov Data Files

`gcov` uses two files for profiling. The names of these files are derived from the original *object* file by substituting the file suffix with either `.gcno`, or `.gcda`. The files contain coverage and profile data stored in a platform-independent format. The `.gcno` files are placed in the same directory as the object file. By default, the `.gcda` files are also stored in the same directory as the object file, but the GCC `-fprofile-dir` option may be used to store the `.gcda` files in a separate directory.

The `.gcno` notes file is generated when the source file is compiled with the GCC `-ftest-coverage` option. It contains information to reconstruct the basic block graphs and assign source line numbers to blocks.

The `.gcda` count data file is generated when a program containing object files built with the GCC `-fprofile-arcs` option is executed. A separate `.gcda` file is created for each object file compiled with this option. It contains arc transition counts, value profile counts, and some summary information.

It is not recommended to access the coverage files directly. Consumers should use the intermediate format that is provided by `gcov` tool via `--json-format` option.

11.5 Data File Relocation to Support Cross-Profiling

Running the program will cause profile output to be generated. For each source file compiled with `-fprofile-arcs`, an accompanying `.gcda` file will be placed in the object file directory. That implicitly requires running the program on the same system as it was built or having the same absolute directory structure on the target system. The program will try to create the needed directory structure, if it is not already present.

To support cross-profiling, a program compiled with `-fprofile-arcs` can relocate the data files based on two environment variables:

- GCOV_PREFIX contains the prefix to add to the absolute paths in the object file. Prefix can be absolute, or relative. The default is no prefix.
- GCOV_PREFIX_STRIP indicates the how many initial directory names to strip off the hardwired absolute paths. Default value is 0.

  Note: If GCOV_PREFIX_STRIP is set without GCOV_PREFIX is undefined, then a relative path is made out of the hardwired absolute paths.

For example, if the object file `/user/build/foo.o` was built with `-fprofile-arcs`, the final executable will try to create the data file `/user/build/foo.gcda` when running on the target system. This will fail if the corresponding directory does not exist and it is unable to create it. This can be overcome by, for example, setting the environment as '`GCOV_PREFIX=/target/run`' and '`GCOV_PREFIX_STRIP=1`'. Such a setting will name the data file `/target/run/build/foo.gcda`.

You must move the data files to the expected directory tree in order to use them for profile directed optimizations (`-fprofile-use`), or to use the `gcov` tool.

11.6 Profiling and Test Coverage in Freestanding Environments

In case your application runs in a hosted environment such as GNU/Linux, then this section is likely not relevant to you. This section is intended for application developers targeting freestanding environments (for example embedded systems) with limited resources. In particular, systems or test cases which do not support constructors/destructors or the C library file I/O. In this section, the *target system* runs your application instrumented for profiling or test coverage. You develop and analyze your application on the *host system*. We now provide an overview how profiling and test coverage can be obtained in this scenario followed by a tutorial which can be exercised on the host system. Finally, some system initialization caveats are listed.

11.6.1 Overview

For an application instrumented for profiling or test coverage, the compiler generates some global data structures which are updated by instrumentation code while the application runs. These data structures are called the *gcov information*. Normally, when the application exits, the gcov information is stored to `.gcda` files. There is one file per translation unit instrumented for profiling or test coverage. The function `__gcov_exit()`, which stores the gcov information to a file, is called by a global destructor function for each translation unit instrumented for profiling or test coverage. It runs at process exit. In a global constructor function, the `__gcov_init()` function is called to register the gcov information of a translation unit in a global list. In some situations, this procedure does not work. Firstly, if you want to profile the global constructor or exit processing of an operating system, the compiler generated functions may conflict with the test objectives. Secondly, you may want to test early parts of the system initialization or abnormal program behaviour which do not allow a global constructor or exit processing. Thirdly, you need a filesystem to store the files.

The `-fprofile-info-section` GCC option enables you to use profiling and test coverage in freestanding environments. This option disables the use of global constructors and destructors for the gcov information. Instead, a pointer to the gcov information is stored in a special linker input section for each translation unit which is compiled with this option. By default, the section name is `.gcov_info`. The gcov information is statically initialized. The pointers to the gcov information from all translation units of an executable can be collected by the linker in a contiguous memory block. For the GNU linker, the below linker script output section definition can be used to achieve this:

```
.gcov_info      :
{
  PROVIDE (__gcov_info_start = .);
  KEEP (*(.gcov_info))
```

```
    PROVIDE (__gcov_info_end = .);
  }
```

The linker will provide two global symbols, `__gcov_info_start` and `__gcov_info_end`, which define the start and end of the array of pointers to gcov information blocks, respectively. The `KEEP ()` directive is required to prevent a garbage collection of the pointers. They are not directly referenced by anything in the executable. The section may be placed in a read-only memory area.

In order to transfer the profiling and test coverage data from the target to the host system, the application has to provide a function to produce a reliable in order byte stream from the target to the host. The byte stream may be compressed and encoded using error detection and correction codes to meet application-specific requirements. The GCC provided `libgcov` target library provides two functions, `__gcov_info_to_gcda()` and `__gcov_filename_to_gcfn()`, to generate a byte stream from a gcov information bock. The functions are declared in `#include <gcov.h>`. The byte stream can be deserialized by the `merge-stream` subcommand of the `gcov-tool` to create or update `.gcda` files in the host filesystem for the instrumented application.

11.6.2 Tutorial

This tutorial should be exercised on the host system. We will build a program instrumented for test coverage. The program runs an application and dumps the gcov information to `stderr` encoded as a printable character stream. The application simply decodes such character streams from `stdin` and writes the decoded character stream to `stdout` (warning: this is binary data). The decoded character stream is consumed by the `merge-stream` subcommand of the `gcov-tool` to create or update the `.gcda` files.

To get started, create an empty directory. Change into the new directory. Then you will create the following three files in this directory

1. `app.h` - a header file included by `app.c` and `main.c`,
2. `app.c` - a source file which contains an example application, and
3. `main.c` - a source file which contains the program main function and code to dump the gcov information.

Firstly, create the header file `app.h` with the following content:

```
static const unsigned char a = 'a';

static inline unsigned char *
encode (unsigned char c, unsigned char buf[2])
{
  buf[0] = c % 16 + a;
  buf[1] = (c / 16) % 16 + a;
  return buf;
}

extern void application (void);
```

Secondly, create the source file `app.c` with the following content:

```
#include "app.h"

#include <stdio.h>

/* The application reads a character stream encoded by encode() from stdin,
```

```
   decodes it, and writes the decoded characters to stdout.  Characters other
   than the 16 characters 'a' to 'p' are ignored.  */

static int can_decode (unsigned char c)
{
  return (unsigned char)(c - a) < 16;
}

void
application (void)
{
  int first = 1;
  int i;
  unsigned char c;

  while ((i = fgetc (stdin)) != EOF)
    {
      unsigned char x = (unsigned char)i;

      if (can_decode (x))
        {
          if (first)
            c = x - a;
          else
            fputc (c + 16 * (x - a), stdout);
          first = !first;
        }
      else
        first = 1;
    }
}
```

Thirdly, create the source file `main.c` with the following content:

```
#include "app.h"

#include <gcov.h>
#include <stdio.h>
#include <stdlib.h>

/* The start and end symbols are provided by the linker script.  We use the
   array notation to avoid issues with a potential small-data area.  */

extern const struct gcov_info *const __gcov_info_start[];
extern const struct gcov_info *const __gcov_info_end[];

/* This function shall produce a reliable in order byte stream to transfer the
   gcov information from the target to the host system.  */

static void
dump (const void *d, unsigned n, void *arg)
{
  (void)arg;
  const unsigned char *c = d;
  unsigned char buf[2];

  for (unsigned i = 0; i < n; ++i)
    fwrite (encode (c[i], buf), sizeof (buf), 1, stderr);
}
```

```
/* The filename is serialized to a gcfn data stream by the
   __gcov_filename_to_gcfn() function.  The gcfn data is used by the
   "merge-stream" subcommand of the "gcov-tool" to figure out the filename
   associated with the gcov information. */

static void
filename (const char *f, void *arg)
{
  __gcov_filename_to_gcfn (f, dump, arg);
}

/* The __gcov_info_to_gcda() function may have to allocate memory under
   certain conditions.  Simply try it out if it is needed for your application
   or not.  */

static void *
allocate (unsigned length, void *arg)
{
  (void)arg;
  return malloc (length);
}

/* Dump the gcov information of all translation units.  */

static void
dump_gcov_info (void)
{
  const struct gcov_info *const *info = __gcov_info_start;
  const struct gcov_info *const *end = __gcov_info_end;

  /* Obfuscate variable to prevent compiler optimizations.  */
  __asm__ ("" : "+r" (info));

  while (info != end)
  {
    void *arg = NULL;
    __gcov_info_to_gcda (*info, filename, dump, allocate, arg);
    fputc ('\n', stderr);
    ++info;
  }
}

/* The main() function just runs the application and then dumps the gcov
   information to stderr.  */

int
main (void)
{
  application ();
  dump_gcov_info ();
  return 0;
}
```

If we compile `app.c` with test coverage and no extra profiling options, then a global constructor (`_sub_I_00100_0` here, it may have a different name in your environment) and destructor (`_sub_D_00100_1`) is used to register and dump the gcov information, respectively. We also see undefined references to `__gcov_init` and `__gcov_exit`:

```
$ gcc --coverage -c app.c
```

```
$ nm app.o
0000000000000000 r a
0000000000000030 T application
0000000000000000 t can_decode
                 U fgetc
                 U fputc
0000000000000000 b __gcov0.application
0000000000000038 b __gcov0.can_decode
0000000000000000 d __gcov_.application
00000000000000c0 d __gcov_.can_decode
                 U __gcov_exit
                 U __gcov_init
                 U __gcov_merge_add
                 U stdin
                 U stdout
0000000000000161 t _sub_D_00100_1
0000000000000151 t _sub_I_00100_0
```

Compile `app.c` and `main.c` with test coverage and `-fprofile-info-section`. Now, a read-only pointer size object is present in the `.gcov_info` section and there are no undefined references to `__gcov_init` and `__gcov_exit`:

```
$ gcc --coverage -fprofile-info-section -c main.c
$ gcc --coverage -fprofile-info-section -c app.c
$ objdump -h app.o

app.o:     file format elf64-x86-64

Sections:
Idx Name          Size      VMA               LMA               File off  Algn
  0 .text         00000151  0000000000000000  0000000000000000  00000040  2**0
                  CONTENTS, ALLOC, LOAD, RELOC, READONLY, CODE
  1 .data         00000100  0000000000000000  0000000000000000  000001a0  2**5
                  CONTENTS, ALLOC, LOAD, RELOC, DATA
  2 .bss          00000040  0000000000000000  0000000000000000  000002a0  2**5
                  ALLOC
  3 .rodata       0000003c  0000000000000000  0000000000000000  000002a0  2**3
                  CONTENTS, ALLOC, LOAD, READONLY, DATA
  4 .gcov_info    00000008  0000000000000000  0000000000000000  000002e0  2**3
                  CONTENTS, ALLOC, LOAD, RELOC, READONLY, DATA
  5 .comment      0000004e  0000000000000000  0000000000000000  000002e8  2**0
                  CONTENTS, READONLY
  6 .note.GNU-stack 00000000  0000000000000000  0000000000000000  00000336  2**0
                  CONTENTS, READONLY
  7 .eh_frame     00000058  0000000000000000  0000000000000000  00000338  2**3
                  CONTENTS, ALLOC, LOAD, RELOC, READONLY, DATA
```

We have to customize the program link procedure so that all the `.gcov_info` linker input sections are placed in a contiguous memory block with a begin and end symbol. Firstly, get the default linker script using the following commands (we assume a GNU linker):

```
$ ld --verbose | sed '1,/^===/d' | sed '/^===/d' > linkcmds
```

Secondly, open the file `linkcmds` with a text editor and place the linker output section definition from the overview after the `.rodata` section definition. Link the program executable using the customized linker script:

```
$ gcc --coverage main.o app.o -T linkcmds -Wl,-Map,app.map
```

In the linker map file `app.map`, we see that the linker placed the read-only pointer size objects of our objects files `main.o` and `app.o` into a contiguous memory block and provided the symbols `__gcov_info_start` and `__gcov_info_end`:

```
$ grep -C 1 "\.gcov_info" app.map

.gcov_info      0x0000000000403ac0       0x10
                0x0000000000403ac0                PROVIDE (__gcov_info_start = .)
 *(.gcov_info)
 .gcov_info     0x0000000000403ac0        0x8 main.o
 .gcov_info     0x0000000000403ac8        0x8 app.o
                0x0000000000403ad0                PROVIDE (__gcov_info_end = .)
```

Make sure no `.gcda` files are present. Run the program with nothing to decode and dump `stderr` to the file `gcda-0.txt` (first run). Run the program to decode `gcda-0.txt` and send it to the `gcov-tool` using the `merge-stream` subcommand to create the `.gcda` files (second run). Run `gcov` to produce a report for `app.c`. We see that the first run with nothing to decode results in a partially covered application:

```
$ rm -f app.gcda main.gcda
$ echo "" | ./a.out 2>gcda-0.txt
$ ./a.out <gcda-0.txt 2>gcda-1.txt | gcov-tool merge-stream
$ gcov -bc app.c
File 'app.c'
Lines executed:69.23% of 13
Branches executed:66.67% of 6
Taken at least once:50.00% of 6
Calls executed:66.67% of 3
Creating 'app.c.gcov'

Lines executed:69.23% of 13
```

Run the program to decode `gcda-1.txt` and send it to the `gcov-tool` using the `merge-stream` subcommand to update the `.gcda` files. Run `gcov` to produce a report for `app.c`. Since the second run decoded the gcov information of the first run, we have now a fully covered application:

```
$ ./a.out <gcda-1.txt 2>gcda-2.txt | gcov-tool merge-stream
$ gcov -bc app.c
File 'app.c'
Lines executed:100.00% of 13
Branches executed:100.00% of 6
Taken at least once:100.00% of 6
Calls executed:100.00% of 3
Creating 'app.c.gcov'

Lines executed:100.00% of 13
```

11.6.3 System Initialization Caveats

The gcov information of a translation unit consists of several global data structures. For example, the instrumented code may update program flow graph edge counters in a zero-initialized data structure. It is safe to run instrumented code before the zero-initialized data is cleared to zero. The coverage information obtained before the zero-initialized data is cleared to zero is unusable. Dumping the gcov information using `__gcov_info_to_gcda()` before the zero-initialized data is cleared to zero or the initialized data is loaded, is undefined behaviour. Clearing the zero-initialized data to zero through a function instrumented for profiling or test coverage is undefined behaviour, since it may produce inconsistent program flow graph edge counters for example.

12 gcov-tool—an Offline Gcda Profile Processing Tool

`gcov-tool` is a tool you can use in conjunction with GCC to manipulate or process gcda profile files offline.

12.1 Introduction to gcov-tool

`gcov-tool` is an offline tool to process gcc's gcda profile files.

Current gcov-tool supports the following functionalities:

- merge two sets of profiles with weights.
- read a stream of profiles with associated filenames and merge it with a set of profiles with weights.
- read one set of profile and rewrite profile contents. One can scale or normalize the count values.

Examples of the use cases for this tool are:

- Collect the profiles for different set of inputs, and use this tool to merge them. One can specify the weight to factor in the relative importance of each input.
- Collect profiles from target systems without a filesystem (freestanding environments). Merge the collected profiles with associated profiles present on the host system. One can specify the weight to factor in the relative importance of each input.
- Rewrite the profile after removing a subset of the gcda files, while maintaining the consistency of the summary and the histogram.
- It can also be used to debug or libgcov code as the tools shares the majority code as the runtime library.

Note that for the merging operation, this profile generated offline may contain slight different values from the online merged profile. Here are a list of typical differences:

- histogram difference: This offline tool recomputes the histogram after merging the counters. The resulting histogram, therefore, is precise. The online merging does not have this capability – the histogram is merged from two histograms and the result is an approximation.
- summary checksum difference: Summary checksum uses a CRC32 operation. The value depends on the link list order of gcov-info objects. This order is different in gcov-tool from that in the online merge. It's expected to have different summary checksums. It does not really matter as the compiler does not use this checksum anywhere.
- value profile counter values difference: Some counter values for value profile are runtime dependent, like heap addresses. It's normal to see some difference in these kind of counters.

12.2 Invoking gcov-tool

```
gcov-tool [global-options] SUB_COMMAND [sub_command-options] profile_dir
```

`gcov-tool` accepts the following options:

`-h`
`--help` Display help about using `gcov-tool` (on the standard output), and exit without doing any further processing.

`-v`
`--version`
Display the `gcov-tool` version number (on the standard output), and exit without doing any further processing.

`merge` Merge two profile directories.

`-o` *directory*
`--output` *directory*
Set the output profile directory. Default output directory name is *merged_profile*.

`-v`
`--verbose`
Set the verbose mode.

`-w` *w1,w2*
`--weight` *w1,w2*
Set the merge weights of the *directory1* and *directory2*, respectively. The default weights are 1 for both.

`merge-stream`
Collect profiles with associated filenames from a *gcfn* and *gcda* data stream. Read the stream from the file specified by *file* or from `stdin`. Merge the profiles with associated profiles in the host filesystem. Apply the optional weights while merging profiles.

For the generation of a *gcfn* and *gcda* data stream on the target system, please have a look at the `__gcov_filename_to_gcfn()` and `__gcov_info_to_gcda()` functions declared in `#include <gcov.h>`.

`-v`
`--verbose`
Set the verbose mode.

`-w` *w1,w2*
`--weight` *w1,w2*
Set the merge weights of the profiles from the *gcfn* and *gcda* data stream and the associated profiles in the host filesystem, respectively. The default weights are 1 for both.

`rewrite` Read the specified profile directory and rewrite to a new directory.

`-n` *long_long_value*
`--normalize <long_long_value>`
Normalize the profile. The specified value is the max counter value in the new profile.

`-o` *directory*
`--output` *directory*
Set the output profile directory. Default output name is *rewrite_profile*.

`-s` *float_or_simple-frac_value*
`--scale` *float_or_simple-frac_value*
: Scale the profile counters. The specified value can be in floating point value, or simple fraction value form, such 1, 2, 2/3, and 5/3.

`-v`
`--verbose`
: Set the verbose mode.

`overlap` Compute the overlap score between the two specified profile directories. The overlap score is computed based on the arc profiles. It is defined as the sum of min (p1_counter[i] / p1_sum_all, p2_counter[i] / p2_sum_all), for all arc counter i, where p1_counter[i] and p2_counter[i] are two matched counters and p1_sum_all and p2_sum_all are the sum of counter values in profile 1 and profile 2, respectively.

`-f`
`--function`
: Print function level overlap score.

`-F`
`--fullname`
: Print full gcda filename.

`-h`
`--hotonly`
: Only print info for hot objects/functions.

`-o`
`--object` Print object level overlap score.

`-t` *float*
`--hot_threshold <float>`
: Set the threshold for hot counter value.

`-v`
`--verbose`
: Set the verbose mode.

13 gcov-dump—an Offline Gcda and Gcno Profile Dump Tool

13.1 Introduction to gcov-dump

`gcov-dump` is a tool you can use in conjunction with GCC to dump content of gcda and gcno profile files offline.

13.2 Invoking gcov-dump

```
Usage: gcov-dump [OPTION] ... gcovfiles
```

`gcov-dump` accepts the following options:

`-h`
`--help` Display help about using `gcov-dump` (on the standard output), and exit without doing any further processing.

`-l`
`--long` Dump content of records.

`-p`
`--positions`
Dump positions of records.

`-r`
`--raw` Print content records in raw format.

`-s`
`--stable` Print content in stable format usable for comparison.

`-v`
`--version`
Display the `gcov-dump` version number (on the standard output), and exit without doing any further processing.

14 `lto-dump`—Tool for dumping LTO object files.

14.1 Introduction to `lto-dump`

`lto-dump` is a tool you can use in conjunction with GCC to dump link time optimization object files.

14.2 Invoking `lto-dump`

```
Usage: lto-dump [OPTION] ... objfiles
```

`lto-dump` accepts the following options:

`-list` Dumps list of details of functions and variables.

`-demangle`
: Dump the demangled output.

`-defined-only`
: Dump only the defined symbols.

`-print-value`
: Dump initial values of the variables.

`-name-sort`
: Sort the symbols alphabetically.

`-size-sort`
: Sort the symbols according to size.

`-reverse-sort`
: Dump the symbols in reverse order.

`-no-sort` Dump the symbols in order of occurrence.

`-symbol=` Dump the details of specific symbol.

`-objects` Dump the details of LTO objects.

`-type-stats`
: Dump the statistics of tree types.

`-tree-stats`
: Dump the statistics of trees.

`-gimple-stats`
: Dump the statistics of gimple statements.

`-dump-level=`
: For deciding the optimization level of body.

`-dump-body=`
: Dump the specific gimple body.

`-help` Display the dump tool help.

15 Known Causes of Trouble with GCC

This section describes known problems that affect users of GCC. Most of these are not GCC bugs per se—if they were, we would fix them. But the result for a user may be like the result of a bug.

Some of these problems are due to bugs in other software, some are missing features that are too much work to add, and some are places where people's opinions differ as to what is best.

15.1 Actual Bugs We Haven't Fixed Yet

- The `fixincludes` script interacts badly with automounters; if the directory of system header files is automounted, it tends to be unmounted while `fixincludes` is running. This would seem to be a bug in the automounter. We don't know any good way to work around it.

15.2 Interoperation

This section lists various difficulties encountered in using GCC together with other compilers or with the assemblers, linkers, libraries and debuggers on certain systems.

- On many platforms, GCC supports a different ABI for C++ than do other compilers, so the object files compiled by GCC cannot be used with object files generated by another C++ compiler.

  An area where the difference is most apparent is name mangling. The use of different name mangling is intentional, to protect you from more subtle problems. Compilers differ as to many internal details of C++ implementation, including: how class instances are laid out, how multiple inheritance is implemented, and how virtual function calls are handled. If the name encoding were made the same, your programs would link against libraries provided from other compilers—but the programs would then crash when run. Incompatible libraries are then detected at link time, rather than at run time.
- On some BSD systems, including some versions of Ultrix, use of profiling causes static variable destructors (currently used only in C++) not to be run.
- On a SPARC, GCC aligns all values of type `double` on an 8-byte boundary, and it expects every `double` to be so aligned. The Sun compiler usually gives `double` values 8-byte alignment, with one exception: function arguments of type `double` may not be aligned.

  As a result, if a function compiled with Sun CC takes the address of an argument of type `double` and passes this pointer of type `double *` to a function compiled with GCC, dereferencing the pointer may cause a fatal signal.

  One way to solve this problem is to compile your entire program with GCC. Another solution is to modify the function that is compiled with Sun CC to copy the argument into a local variable; local variables are always properly aligned. A third solution is to modify the function that uses the pointer to dereference it via the following function `access_double` instead of directly with '`*`':

  ```
  inline double
  ```

```
access_double (double *unaligned_ptr)
{
  union d2i { double d; int i[2]; };

  union d2i *p = (union d2i *) unaligned_ptr;
  union d2i u;

  u.i[0] = p->i[0];
  u.i[1] = p->i[1];

  return u.d;
}
```

Storing into the pointer can be done likewise with the same union.

- On Solaris, the `malloc` function in the `libmalloc.a` library may allocate memory that is only 4 byte aligned. Since GCC on the SPARC assumes that doubles are 8 byte aligned, this may result in a fatal signal if doubles are stored in memory allocated by the `libmalloc.a` library.

  The solution is to not use the `libmalloc.a` library. Use instead `malloc` and related functions from `libc.a`; they do not have this problem.
- On the HP PA machine, ADB sometimes fails to work on functions compiled with GCC. Specifically, it fails to work on functions that use `alloca` or variable-size arrays. This is because GCC doesn't generate HP-UX unwind descriptors for such functions. It may even be impossible to generate them.
- Debugging (`-g`) is not supported on the HP PA machine, unless you use the preliminary GNU tools.
- Taking the address of a label may generate errors from the HP-UX PA assembler. GAS for the PA does not have this problem.
- Using floating point parameters for indirect calls to static functions will not work when using the HP assembler. There simply is no way for GCC to specify what registers hold arguments for static functions when using the HP assembler. GAS for the PA does not have this problem.
- In extremely rare cases involving some very large functions you may receive errors from the HP linker complaining about an out of bounds unconditional branch offset. This used to occur more often in previous versions of GCC, but is now exceptionally rare. If you should run into it, you can work around by making your function smaller.
- GCC compiled code sometimes emits warnings from the HP-UX assembler of the form:

  ```
  (warning) Use of GR3 when
    frame >= 8192 may cause conflict.
  ```

  These warnings are harmless and can be safely ignored.
- In extremely rare cases involving some very large functions you may receive errors from the AIX Assembler complaining about a displacement that is too large. If you should run into it, you can work around by making your function smaller.
- The `libstdc++.a` library in GCC relies on the SVR4 dynamic linker semantics which merges global symbols between libraries and applications, especially necessary for C++ streams functionality. This is not the default behavior of AIX shared libraries and dynamic linking. `libstdc++.a` is built on AIX with "runtime-linking" enabled so that symbol merging can occur. To utilize this feature, the application linked with

libstdc++.a must include the -Wl,-brtl flag on the link line. G++ cannot impose this because this option may interfere with the semantics of the user program and users may not always use 'g++' to link his or her application. Applications are not required to use the -Wl,-brtl flag on the link line—the rest of the libstdc++.a library which is not dependent on the symbol merging semantics will continue to function correctly.

- An application can interpose its own definition of functions for functions invoked by libstdc++.a with "runtime-linking" enabled on AIX. To accomplish this the application must be linked with "runtime-linking" option and the functions explicitly must be exported by the application (-Wl,-brtl,-bE:exportfile).
- AIX on the RS/6000 provides support (NLS) for environments outside of the United States. Compilers and assemblers use NLS to support locale-specific representations of various objects including floating-point numbers ('.' vs ',' for separating decimal fractions). There have been problems reported where the library linked with GCC does not produce the same floating-point formats that the assembler accepts. If you have this problem, set the LANG environment variable to 'C' or 'En_US'.
- Even if you specify -fdollars-in-identifiers, you cannot successfully use '$' in identifiers on the RS/6000 due to a restriction in the IBM assembler. GAS supports these identifiers.

15.3 Incompatibilities of GCC

There are several noteworthy incompatibilities between GNU C and K&R (non-ISO) versions of C.

- GCC normally makes string constants read-only. If several identical-looking string constants are used, GCC stores only one copy of the string.

  One consequence is that you cannot call mktemp with a string constant argument. The function mktemp always alters the string its argument points to.

  Another consequence is that sscanf does not work on some very old systems when passed a string constant as its format control string or input. This is because sscanf incorrectly tries to write into the string constant. Likewise fscanf and scanf.

  The solution to these problems is to change the program to use char-array variables with initialization strings for these purposes instead of string constants.
- -2147483648 is positive.

  This is because 2147483648 cannot fit in the type int, so (following the ISO C rules) its data type is unsigned long int. Negating this value yields 2147483648 again.
- GCC does not substitute macro arguments when they appear inside of string constants. For example, the following macro in GCC

  ```
  #define foo(a) "a"
  ```

  will produce output "a" regardless of what the argument *a* is.
- When you use setjmp and longjmp, the only automatic variables guaranteed to remain valid are those declared volatile. This is a consequence of automatic register allocation. Consider this function:

  ```
  jmp_buf j;

  foo ()
  ```

```
{
  int a, b;

  a = fun1 ();
  if (setjmp (j))
    return a;

  a = fun2 ();
  /* longjmp (j) may occur in fun3. */
  return a + fun3 ();
}
```

Here `a` may or may not be restored to its first value when the `longjmp` occurs. If `a` is allocated in a register, then its first value is restored; otherwise, it keeps the last value stored in it.

If you use the `-W` option with the `-O` option, you will get a warning when GCC thinks such a problem might be possible.

- Programs that use preprocessing directives in the middle of macro arguments do not work with GCC. For example, a program like this will not work:

```
foobar (
#define luser
        hack)
```

  ISO C does not permit such a construct.

- K&R compilers allow comments to cross over an inclusion boundary (i.e. started in an include file and ended in the including file).
- Declarations of external variables and functions within a block apply only to the block containing the declaration. In other words, they have the same scope as any other declaration in the same place.

  In some other C compilers, an `extern` declaration affects all the rest of the file even if it happens within a block.

- In traditional C, you can combine `long`, etc., with a typedef name, as shown here:

```
typedef int foo;
typedef long foo bar;
```

  In ISO C, this is not allowed: `long` and other type modifiers require an explicit `int`.

- PCC allows typedef names to be used as function parameters.
- Traditional C allows the following erroneous pair of declarations to appear together in a given scope:

```
typedef int foo;
typedef foo foo;
```

- GCC treats all characters of identifiers as significant. According to K&R-1 (2.2), "No more than the first eight characters are significant, although more may be used.". Also according to K&R-1 (2.2), "An identifier is a sequence of letters and digits; the first character must be a letter. The underscore _ counts as a letter.", but GCC also allows dollar signs in identifiers.
- PCC allows whitespace in the middle of compound assignment operators such as '`+=`'. GCC, following the ISO standard, does not allow this.
- GCC complains about unterminated character constants inside of preprocessing conditionals that fail. Some programs have English comments enclosed in conditionals

that are guaranteed to fail; if these comments contain apostrophes, GCC will probably report an error. For example, this code would produce an error:

```
#if 0
You can't expect this to work.
#endif
```

The best solution to such a problem is to put the text into an actual C comment delimited by '`/*...*/`'.

- Many user programs contain the declaration '`long time ();`'. In the past, the system header files on many systems did not actually declare `time`, so it did not matter what type your program declared it to return. But in systems with ISO C headers, `time` is declared to return `time_t`, and if that is not the same as `long`, then '`long time ();`' is erroneous.

  The solution is to change your program to use appropriate system headers (`<time.h>` on systems with ISO C headers) and not to declare `time` if the system header files declare it, or failing that to use `time_t` as the return type of `time`.

- When compiling functions that return `float`, PCC converts it to a double. GCC actually returns a `float`. If you are concerned with PCC compatibility, you should declare your functions to return `double`; you might as well say what you mean.

- When compiling functions that return structures or unions, GCC output code normally uses a method different from that used on most versions of Unix. As a result, code compiled with GCC cannot call a structure-returning function compiled with PCC, and vice versa.

  The method used by GCC is as follows: a structure or union which is 1, 2, 4 or 8 bytes long is returned like a scalar. A structure or union with any other size is stored into an address supplied by the caller (usually in a special, fixed register, but on some machines it is passed on the stack). The target hook `TARGET_STRUCT_VALUE_RTX` tells GCC where to pass this address.

  By contrast, PCC on most target machines returns structures and unions of any size by copying the data into an area of static storage, and then returning the address of that storage as if it were a pointer value. The caller must copy the data from that memory area to the place where the value is wanted. GCC does not use this method because it is slower and nonreentrant.

  On some newer machines, PCC uses a reentrant convention for all structure and union returning. GCC on most of these machines uses a compatible convention when returning structures and unions in memory, but still returns small structures and unions in registers.

  You can tell GCC to use a compatible convention for all structure and union returning with the option `-fpcc-struct-return`.

- GCC complains about program fragments such as '`0x74ae-0x4000`' which appear to be two hexadecimal constants separated by the minus operator. Actually, this string is a single *preprocessing token*. Each such token must correspond to one token in C. Since this does not, GCC prints an error message. Although it may appear obvious that what is meant is an operator and two values, the ISO C standard specifically requires that this be treated as erroneous.

A *preprocessing token* is a *preprocessing number* if it begins with a digit and is followed by letters, underscores, digits, periods and 'e+', 'e-', 'E+', 'E-', 'p+', 'p-', 'P+', or 'P-' character sequences. (In strict C90 mode, the sequences 'p+', 'p-', 'P+' and 'P-' cannot appear in preprocessing numbers.)

To make the above program fragment valid, place whitespace in front of the minus sign. This whitespace will end the preprocessing number.

15.4 Fixed Header Files

GCC needs to install corrected versions of some system header files. This is because most target systems have some header files that won't work with GCC unless they are changed. Some have bugs, some are incompatible with ISO C, and some depend on special features of other compilers.

Installing GCC automatically creates and installs the fixed header files, by running a program called `fixincludes`. Normally, you don't need to pay attention to this. But there are cases where it doesn't do the right thing automatically.

- If you update the system's header files, such as by installing a new system version, the fixed header files of GCC are not automatically updated. They can be updated using the `mkheaders` script installed in `*libexecdir*/gcc/*target*/*version*/install-tools/`.
- On some systems, header file directories contain machine-specific symbolic links in certain places. This makes it possible to share most of the header files among hosts running the same version of the system on different machine models.

  The programs that fix the header files do not understand this special way of using symbolic links; therefore, the directory of fixed header files is good only for the machine model used to build it.

  It is possible to make separate sets of fixed header files for the different machine models, and arrange a structure of symbolic links so as to use the proper set, but you'll have to do this by hand.

15.5 Standard Libraries

GCC by itself attempts to provide the compiler part of a conforming implementation, but only a limited subset of the library part of such an implementation. See Chapter 2 [Language Standards Supported by GCC], page 3, for details of what this means. Beyond the limited library facilities described there, the rest of the C library is supplied by the vendor of the operating system. If that C library doesn't conform to the C standards, then your programs might get warnings (especially when using `-Wall`) that you don't expect.

For example, the `sprintf` function on SunOS 4.1.3 returns `char *` while the C standard says that `sprintf` returns an `int`. The `fixincludes` program could make the prototype for this function match the Standard, but that would be wrong, since the function will still return `char *`.

If you need a Standard compliant library, then you need to find one, as GCC does not provide one. The GNU C library (called `glibc`) provides ISO C, POSIX, BSD, SystemV and X/Open compatibility for GNU/Linux and HURD-based GNU systems; no recent version of it supports other systems, though some very old versions did. Version 2.2 of the GNU

C library includes nearly complete C99 support. You could also ask your operating system vendor if newer libraries are available.

15.6 Disappointments and Misunderstandings

These problems are perhaps regrettable, but we don't know any practical way around them.

- Certain local variables aren't recognized by debuggers when you compile with optimization.

  This occurs because sometimes GCC optimizes the variable out of existence. There is no way to tell the debugger how to compute the value such a variable "would have had", and it is not clear that would be desirable anyway. So GCC simply does not mention the eliminated variable when it writes debugging information.

  You have to expect a certain amount of disagreement between the executable and your source code, when you use optimization.

- Users often think it is a bug when GCC reports an error for code like this:

  ```
  int foo (struct mumble *);

  struct mumble { ... };

  int foo (struct mumble *x)
  { ... }
  ```

  This code really is erroneous, because the scope of `struct mumble` in the prototype is limited to the argument list containing it. It does not refer to the `struct mumble` defined with file scope immediately below—they are two unrelated types with similar names in different scopes.

  But in the definition of `foo`, the file-scope type is used because that is available to be inherited. Thus, the definition and the prototype do not match, and you get an error.

  This behavior may seem silly, but it's what the ISO standard specifies. It is easy enough for you to make your code work by moving the definition of `struct mumble` above the prototype. It's not worth being incompatible with ISO C just to avoid an error for the example shown above.

- Accesses to bit-fields even in volatile objects works by accessing larger objects, such as a byte or a word. You cannot rely on what size of object is accessed in order to read or write the bit-field; it may even vary for a given bit-field according to the precise usage.

  If you care about controlling the amount of memory that is accessed, use volatile but do not use bit-fields.

- GCC comes with shell scripts to fix certain known problems in system header files. They install corrected copies of various header files in a special directory where only GCC will normally look for them. The scripts adapt to various systems by searching all the system header files for the problem cases that we know about.

  If new system header files are installed, nothing automatically arranges to update the corrected header files. They can be updated using the `mkheaders` script installed in *`libexecdir`*`/gcc/`*`target`*`/`*`version`*`/install-tools/`.

- On 68000 and x86 systems, for instance, you can get paradoxical results if you test the precise values of floating point numbers. For example, you can find that a floating point value which is not a NaN is not equal to itself. This results from the fact that the floating point registers hold a few more bits of precision than fit in a `double` in memory. Compiled code moves values between memory and floating point registers at its convenience, and moving them into memory truncates them.

You can partially avoid this problem by using the `-ffloat-store` option (see Section 3.12 [Optimize Options], page 194).

- On AIX and other platforms without weak symbol support, templates need to be instantiated explicitly and symbols for static members of templates will not be generated.
- On AIX, GCC scans object files and library archives for static constructors and destructors when linking an application before the linker prunes unreferenced symbols. This is necessary to prevent the AIX linker from mistakenly assuming that static constructor or destructor are unused and removing them before the scanning can occur. All static constructors and destructors found will be referenced even though the modules in which they occur may not be used by the program. This may lead to both increased executable size and unexpected symbol references.

15.7 Common Misunderstandings with GNU C++

C++ is a complex language and an evolving one, and its standard definition (the ISO C++ standard) was only recently completed. As a result, your C++ compiler may occasionally surprise you, even when its behavior is correct. This section discusses some areas that frequently give rise to questions of this sort.

15.7.1 Declare *and* Define Static Members

When a class has static data members, it is not enough to *declare* the static member; you must also *define* it. For example:

```
class Foo
{
  ...
  void method();
  static int bar;
};
```

This declaration only establishes that the class `Foo` has an `int` named `Foo::bar`, and a member function named `Foo::method`. But you still need to define *both* `method` and `bar` elsewhere. According to the ISO standard, you must supply an initializer in one (and only one) source file, such as:

```
int Foo::bar = 0;
```

Other C++ compilers may not correctly implement the standard behavior. As a result, when you switch to `g++` from one of these compilers, you may discover that a program that appeared to work correctly in fact does not conform to the standard: `g++` reports as undefined symbols any static data members that lack definitions.

15.7.2 Name Lookup, Templates, and Accessing Members of Base Classes

The C++ standard prescribes that all names that are not dependent on template parameters are bound to their present definitions when parsing a template function or class.[1] Only names that are dependent are looked up at the point of instantiation. For example, consider

```
void foo(double);

struct A {
  template <typename T>
  void f () {
    foo (1);        // 1
    int i = N;      // 2
    T t;
    t.bar();        // 3
    foo (t);        // 4
  }

  static const int N;
};
```

Here, the names `foo` and `N` appear in a context that does not depend on the type of `T`. The compiler will thus require that they are defined in the context of use in the template, not only before the point of instantiation, and will here use `::foo(double)` and `A::N`, respectively. In particular, it will convert the integer value to a `double` when passing it to `::foo(double)`.

Conversely, `bar` and the call to `foo` in the fourth marked line are used in contexts that do depend on the type of `T`, so they are only looked up at the point of instantiation, and you can provide declarations for them after declaring the template, but before instantiating it. In particular, if you instantiate `A::f<int>`, the last line will call an overloaded `::foo(int)` if one was provided, even if after the declaration of `struct A`.

This distinction between lookup of dependent and non-dependent names is called two-stage (or dependent) name lookup. G++ implements it since version 3.4.

Two-stage name lookup sometimes leads to situations with behavior different from non-template codes. The most common is probably this:

```
template <typename T> struct Base {
  int i;
};

template <typename T> struct Derived : public Base<T> {
  int get_i() { return i; }
};
```

In `get_i()`, `i` is not used in a dependent context, so the compiler will look for a name declared at the enclosing namespace scope (which is the global scope here). It will not look into the base class, since that is dependent and you may declare specializations of `Base` even after declaring `Derived`, so the compiler cannot really know what `i` would refer to. If there is no global variable `i`, then you will get an error message.

In order to make it clear that you want the member of the base class, you need to defer lookup until instantiation time, at which the base class is known. For this, you need to

---

[1] The C++ standard just uses the term "dependent" for names that depend on the type or value of template parameters. This shorter term will also be used in the rest of this section.

access `i` in a dependent context, by either using `this->i` (remember that `this` is of type `Derived<T>*`, so is obviously dependent), or using `Base<T>::i`. Alternatively, `Base<T>::i` might be brought into scope by a `using`-declaration.

Another, similar example involves calling member functions of a base class:

```
template <typename T> struct Base {
    int f();
};

template <typename T> struct Derived : Base<T> {
    int g() { return f(); };
};
```

Again, the call to `f()` is not dependent on template arguments (there are no arguments that depend on the type `T`, and it is also not otherwise specified that the call should be in a dependent context). Thus a global declaration of such a function must be available, since the one in the base class is not visible until instantiation time. The compiler will consequently produce the following error message:

```
x.cc: In member function `int Derived<T>::g()':
x.cc:6: error: there are no arguments to `f' that depend on a template
   parameter, so a declaration of `f' must be available
x.cc:6: error: (if you use `-fpermissive', G++ will accept your code, but
   allowing the use of an undeclared name is deprecated)
```

To make the code valid either use `this->f()`, or `Base<T>::f()`. Using the `-fpermissive` flag will also let the compiler accept the code, by marking all function calls for which no declaration is visible at the time of definition of the template for later lookup at instantiation time, as if it were a dependent call. We do not recommend using `-fpermissive` to work around invalid code, and it will also only catch cases where functions in base classes are called, not where variables in base classes are used (as in the example above).

Note that some compilers (including G++ versions prior to 3.4) get these examples wrong and accept above code without an error. Those compilers do not implement two-stage name lookup correctly.

15.7.3 Temporaries May Vanish Before You Expect

It is dangerous to use pointers or references to *portions* of a temporary object. The compiler may very well delete the object before you expect it to, leaving a pointer to garbage. The most common place where this problem crops up is in classes like string classes, especially ones that define a conversion function to type `char *` or `const char *`—which is one reason why the standard `string` class requires you to call the `c_str` member function. However, any class that returns a pointer to some internal structure is potentially subject to this problem.

For example, a program may use a function `strfunc` that returns `string` objects, and another function `charfunc` that operates on pointers to `char`:

```
string strfunc ();
void charfunc (const char *);

void
f ()
{
  const char *p = strfunc().c_str();
  ...
```

```
    charfunc (p);
    ...
    charfunc (p);
  }
```

In this situation, it may seem reasonable to save a pointer to the C string returned by the `c_str` member function and use that rather than call `c_str` repeatedly. However, the temporary string created by the call to `strfunc` is destroyed after `p` is initialized, at which point `p` is left pointing to freed memory.

Code like this may run successfully under some other compilers, particularly obsolete cfront-based compilers that delete temporaries along with normal local variables. However, the GNU C++ behavior is standard-conforming, so if your program depends on late destruction of temporaries it is not portable.

The safe way to write such code is to give the temporary a name, which forces it to remain until the end of the scope of the name. For example:

```
const string& tmp = strfunc ();
charfunc (tmp.c_str ());
```

15.7.4 Implicit Copy-Assignment for Virtual Bases

When a base class is virtual, only one subobject of the base class belongs to each full object. Also, the constructors and destructors are invoked only once, and called from the most-derived class. However, such objects behave unspecified when being assigned. For example:

```
struct Base{
  char *name;
  Base(const char *n) : name(strdup(n)){}
  Base& operator= (const Base& other){
   free (name);
   name = strdup (other.name);
   return *this;
  }
};

struct A:virtual Base{
  int val;
  A():Base("A"){}
};

struct B:virtual Base{
  int bval;
  B():Base("B"){}
};

struct Derived:public A, public B{
  Derived():Base("Derived"){}
};

void func(Derived &d1, Derived &d2)
{
  d1 = d2;
}
```

The C++ standard specifies that '`Base::Base`' is only called once when constructing or copy-constructing a Derived object. It is unspecified whether '`Base::operator=`' is called more than once when the implicit copy-assignment for Derived objects is invoked (as it is inside '`func`' in the example).

G++ implements the "intuitive" algorithm for copy-assignment: assign all direct bases, then assign all members. In that algorithm, the virtual base subobject can be encountered more than once. In the example, copying proceeds in the following order: '`name`' (via `strdup`), '`val`', '`name`' again, and '`bval`'.

If application code relies on copy-assignment, a user-defined copy-assignment operator removes any uncertainties. With such an operator, the application can define whether and how the virtual base subobject is assigned.

15.8 Certain Changes We Don't Want to Make

This section lists changes that people frequently request, but which we do not make because we think GCC is better without them.

- Checking the number and type of arguments to a function which has an old-fashioned definition and no prototype.

  Such a feature would work only occasionally—only for calls that appear in the same file as the called function, following the definition. The only way to check all calls reliably is to add a prototype for the function. But adding a prototype eliminates the motivation for this feature. So the feature is not worthwhile.

- Warning about using an expression whose type is signed as a shift count.

  Shift count operands are probably signed more often than unsigned. Warning about this would cause far more annoyance than good.

- Warning about assigning a signed value to an unsigned variable.

  Such assignments must be very common; warning about them would cause more annoyance than good.

- Warning when a non-void function value is ignored.

  C contains many standard functions that return a value that most programs choose to ignore. One obvious example is `printf`. Warning about this practice only leads the defensive programmer to clutter programs with dozens of casts to `void`. Such casts are required so frequently that they become visual noise. Writing those casts becomes so automatic that they no longer convey useful information about the intentions of the programmer. For functions where the return value should never be ignored, use the `warn_unused_result` function attribute (see Section 6.4.1 [Function Attributes], page 621).

- Making `-fshort-enums` the default.

  This would cause storage layout to be incompatible with most other C compilers. And it doesn't seem very important, given that you can get the same result in other ways. The case where it matters most is when the enumeration-valued object is inside a structure, and in that case you can specify a field width explicitly.

- Making bit-fields unsigned by default on particular machines where "the ABI standard" says to do so.

  The ISO C standard leaves it up to the implementation whether a bit-field declared plain `int` is signed or not. This in effect creates two alternative dialects of C.

The GNU C compiler supports both dialects; you can specify the signed dialect with `-fsigned-bitfields` and the unsigned dialect with `-funsigned-bitfields`. However, this leaves open the question of which dialect to use by default.

Currently, the preferred dialect makes plain bit-fields signed, because this is simplest. Since `int` is the same as `signed int` in every other context, it is cleanest for them to be the same in bit-fields as well.

Some computer manufacturers have published Application Binary Interface standards which specify that plain bit-fields should be unsigned. It is a mistake, however, to say anything about this issue in an ABI. This is because the handling of plain bit-fields distinguishes two dialects of C. Both dialects are meaningful on every type of machine. Whether a particular object file was compiled using signed bit-fields or unsigned is of no concern to other object files, even if they access the same bit-fields in the same data structures.

A given program is written in one or the other of these two dialects. The program stands a chance to work on most any machine if it is compiled with the proper dialect. It is unlikely to work at all if compiled with the wrong dialect.

Many users appreciate the GNU C compiler because it provides an environment that is uniform across machines. These users would be inconvenienced if the compiler treated plain bit-fields differently on certain machines.

Occasionally users write programs intended only for a particular machine type. On these occasions, the users would benefit if the GNU C compiler were to support by default the same dialect as the other compilers on that machine. But such applications are rare. And users writing a program to run on more than one type of machine cannot possibly benefit from this kind of compatibility.

This is why GCC does and will treat plain bit-fields in the same fashion on all types of machines (by default).

There are some arguments for making bit-fields unsigned by default on all machines. If, for example, this becomes a universal de facto standard, it would make sense for GCC to go along with it. This is something to be considered in the future.

(Of course, users strongly concerned about portability should indicate explicitly in each bit-field whether it is signed or not. In this way, they write programs which have the same meaning in both C dialects.)

- Undefining `__STDC__` when `-ansi` is not used.

  Currently, GCC defines `__STDC__` unconditionally. This provides good results in practice.

  Programmers normally use conditionals on `__STDC__` to ask whether it is safe to use certain features of ISO C, such as function prototypes or ISO token concatenation. Since plain `gcc` supports all the features of ISO C, the correct answer to these questions is "yes".

  Some users try to use `__STDC__` to check for the availability of certain library facilities. This is actually incorrect usage in an ISO C program, because the ISO C standard says that a conforming freestanding implementation should define `__STDC__` even though it does not have the library facilities. '`gcc -ansi -pedantic`' is a conforming freestanding implementation, and it is therefore required to define `__STDC__`, even though it does not come with an ISO C library.

Sometimes people say that defining `__STDC__` in a compiler that does not completely conform to the ISO C standard somehow violates the standard. This is illogical. The standard is a standard for compilers that claim to support ISO C, such as '`gcc -ansi`'—not for other compilers such as plain `gcc`. Whatever the ISO C standard says is relevant to the design of plain `gcc` without `-ansi` only for pragmatic reasons, not as a requirement.

GCC normally defines `__STDC__` to be 1, and in addition defines `__STRICT_ANSI__` if you specify the `-ansi` option, or a `-std` option for strict conformance to some version of ISO C. On some hosts, system include files use a different convention, where `__STDC__` is normally 0, but is 1 if the user specifies strict conformance to the C Standard. GCC follows the host convention when processing system include files, but when processing user files it follows the usual GNU C convention.

- Undefining `__STDC__` in C++.

  Programs written to compile with C++-to-C translators get the value of `__STDC__` that goes with the C compiler that is subsequently used. These programs must test `__STDC__` to determine what kind of C preprocessor that compiler uses: whether they should concatenate tokens in the ISO C fashion or in the traditional fashion.

  These programs work properly with GNU C++ if `__STDC__` is defined. They would not work otherwise.

  In addition, many header files are written to provide prototypes in ISO C but not in traditional C. Many of these header files can work without change in C++ provided `__STDC__` is defined. If `__STDC__` is not defined, they will all fail, and will all need to be changed to test explicitly for C++ as well.

- Deleting "empty" loops.

  Historically, GCC has not deleted "empty" loops under the assumption that the most likely reason you would put one in a program is to have a delay, so deleting them will not make real programs run any faster.

  However, the rationale here is that optimization of a nonempty loop cannot produce an empty one. This held for carefully written C compiled with less powerful optimizers but is not always the case for carefully written C++ or with more powerful optimizers. Thus GCC will remove operations from loops whenever it can determine those operations are not externally visible (apart from the time taken to execute them, of course). In case the loop can be proved to be finite, GCC will also remove the loop itself.

  Be aware of this when performing timing tests, for instance the following loop can be completely removed, provided `some_expression` can provably not change any global state.

  ```
  {
    int sum = 0;
    int ix;

    for (ix = 0; ix != 10000; ix++)
      sum += some_expression;
  }
  ```

  Even though `sum` is accumulated in the loop, no use is made of that summation, so the accumulation can be removed.

- Making side effects happen in the same order as in some other compiler.

It is never safe to depend on the order of evaluation of side effects. For example, a function call like this may very well behave differently from one compiler to another:

```
void func (int, int);

int i = 2;
func (i++, i++);
```

There is no guarantee (in either the C or the C++ standard language definitions) that the increments will be evaluated in any particular order. Either increment might happen first. `func` might get the arguments '`2, 3`', or it might get '`3, 2`', or even '`2, 2`'.

- Making certain warnings into errors by default.

  Some ISO C testsuites report failure when the compiler does not produce an error message for a certain program.

  ISO C requires a "diagnostic" message for certain kinds of invalid programs, but a warning is defined by GCC to count as a diagnostic. If GCC produces a warning but not an error, that is correct ISO C support. If testsuites call this "failure", they should be run with the GCC option `-pedantic-errors`, which will turn these warnings into errors.

15.9 Warning Messages and Error Messages

The GNU compiler can produce two kinds of diagnostics: errors and warnings. Each kind has a different purpose:

> *Errors* report problems that make it impossible to compile your program. GCC reports errors with the source file name and line number where the problem is apparent.
>
> *Warnings* report other unusual conditions in your code that *may* indicate a problem, although compilation can (and does) proceed. Warning messages also report the source file name and line number, but include the text '`warning:`' to distinguish them from error messages.

Warnings may indicate danger points where you should check to make sure that your program really does what you intend; or the use of obsolete features; or the use of nonstandard features of GNU C or C++. Many warnings are issued only if you ask for them, with one of the `-W` options (for instance, `-Wall` requests a variety of useful warnings).

GCC always tries to compile your program if possible; it never gratuitously rejects a program whose meaning is clear merely because (for instance) it fails to conform to a standard. In some cases, however, the C and C++ standards specify that certain extensions are forbidden, and a diagnostic *must* be issued by a conforming compiler. The `-pedantic` option tells GCC to issue warnings in such cases; `-pedantic-errors` says to make them errors instead. This does not mean that *all* non-ISO constructs get warnings or errors.

See Section 3.9 [Options to Request or Suppress Warnings], page 100, for more detail on these and related command-line options.

16 Reporting Bugs

Your bug reports play an essential role in making GCC reliable.

When you encounter a problem, the first thing to do is to see if it is already known. See Chapter 15 [Trouble], page 1129. If it isn't known, then you should report the problem.

16.1 Have You Found a Bug?

If you are not sure whether you have found a bug, here are some guidelines:

- If the compiler gets a fatal signal, for any input whatever, that is a compiler bug. Reliable compilers never crash.
- If the compiler produces invalid assembly code, for any input whatever (except an `asm` statement), that is a compiler bug, unless the compiler reports errors (not just warnings) which would ordinarily prevent the assembler from being run.
- If the compiler produces valid assembly code that does not correctly execute the input source code, that is a compiler bug.

  However, you must double-check to make sure, because you may have a program whose behavior is undefined, which happened by chance to give the desired results with another C or C++ compiler.

  Problems often result from expressions with two increment operators, as in `f (*p++, *p++)`. Your previous compiler might have interpreted that expression the way you intended; GCC might interpret it another way. Neither compiler is wrong. The bug is in your code.

  After you have localized the error to a single source line, it should be easy to check for these things. If your program is correct and well defined, you have found a compiler bug.
- If the compiler produces an error message for valid input, that is a compiler bug.
- If the compiler does not produce an error message for invalid input, that is a compiler bug. However, you should note that your idea of "invalid input" might be someone else's idea of "an extension" or "support for traditional practice".
- If you are an experienced user of one of the languages GCC supports, your suggestions for improvement of GCC are welcome in any case.

16.2 How and Where to Report Bugs

Bugs should be reported to the bug database at `https://gcc.gnu.org/bugs/`.

17 How To Get Help with GCC

If you need help installing, using or changing GCC, there are two ways to find it:

- Send a message to a suitable network mailing list. First try `gcc-help@gcc.gnu.org` (for help installing or using GCC), and if that brings no response, try `gcc@gcc.gnu.org`. For help changing GCC, ask `gcc@gcc.gnu.org`. If you think you have found a bug in GCC, please report it following the instructions at see Section 16.2 [Bug Reporting], page 1145.
- Look in the service directory for someone who might help you for a fee. The service directory is found at `https://www.fsf.org/resources/service`.

For further information, see `https://gcc.gnu.org/faq.html#support`.

18 Contributing to GCC Development

If you would like to help pretest GCC releases to assure they work well, current development sources are available via Git (see `https://gcc.gnu.org/git.html`). Source and binary snapshots are also available for FTP; see `https://gcc.gnu.org/snapshots.html`.

If you would like to work on improvements to GCC, please read the advice at these URLs:

```
https://gcc.gnu.org/contribute.html
https://gcc.gnu.org/contributewhy.html
```

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For more information, see:

```
https://www.gnu.org/
https://www.gnu.org/gnu/linux-and-gnu.html
```

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Version 3, 29 June 2007

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- Analog Devices helped implement the support for complex data types and iterators.
- John David Anglin for threading-related fixes and improvements to libstdc++-v3, and the HP-UX port.
- James van Artsdalen wrote the code that makes efficient use of the Intel 80387 register stack.
- Abramo and Roberto Bagnara for the SysV68 Motorola 3300 Delta Series port.
- Alasdair Baird for various bug fixes.
- Giovanni Bajo for analyzing lots of complicated C++ problem reports.
- Peter Barada for his work to improve code generation for new ColdFire cores.
- Gerald Baumgartner added the signature extension to the C++ front end.
- Godmar Back for his Java improvements and encouragement.
- Scott Bambrough for help porting the Java compiler.
- Wolfgang Bangerth for processing tons of bug reports.
- Jon Beniston for his Microsoft Windows port of Java and port to Lattice Mico32.
- Daniel Berlin for better DWARF 2 support, faster/better optimizations, improved alias analysis, plus migrating GCC to Bugzilla.
- Geoff Berry for his Java object serialization work and various patches.
- Richard Biener for his ongoing middle-end contributions and bug fixes and for release management.
- David Binderman for testing GCC trunk against Fedora Rawhide and csmith.
- Laurynas Biveinis for memory management work and DJGPP port fixes.
- Uros Bizjak for the implementation of x87 math built-in functions and for various middle end and i386 back end improvements and bug fixes.
- Eric Blake for helping to make GCJ and libgcj conform to the specifications.
- Janne Blomqvist for contributions to GNU Fortran.
- Hans-J. Boehm for his garbage collector, IA-64 libffi port, and other Java work.
- Segher Boessenkool for helping maintain the PowerPC port and the instruction combiner plus various contributions to the middle end.
- Neil Booth for work on cpplib, lang hooks, debug hooks and other miscellaneous clean-ups.
- Steven Bosscher for integrating the GNU Fortran front end into GCC and for contributing to the tree-ssa branch.
- Eric Botcazou for fixing middle- and backend bugs left and right.

- Per Bothner for his direction via the steering committee and various improvements to the infrastructure for supporting new languages. Chill front end implementation. Initial implementations of cpplib, fix-header, config.guess, libio, and past C++ library (libg++) maintainer. Dreaming up, designing and implementing much of GCJ.
- Devon Bowen helped port GCC to the Tahoe.
- Don Bowman for mips-vxworks contributions.
- James Bowman for the FT32 port.
- Dave Brolley for work on cpplib and Chill.
- Paul Brook for work on the ARM architecture and maintaining GNU Fortran.
- Robert Brown implemented the support for Encore 32000 systems.
- Christian Bruel for improvements to local store elimination.
- Herman A.J. ten Brugge for various fixes.
- Joerg Brunsmann for Java compiler hacking and help with the GCJ FAQ.
- Joe Buck for his direction via the steering committee from its creation to 2013.
- Iain Buclaw for the D frontend.
- Craig Burley for leadership of the G77 Fortran effort.
- Tobias Burnus for contributions to GNU Fortran.
- Stephan Buys for contributing Doxygen notes for libstdc++.
- Paolo Carlini for libstdc++ work: lots of efficiency improvements to the C++ strings, streambufs and formatted I/O, hard detective work on the frustrating localization issues, and keeping up with the problem reports.
- John Carr for his alias work, SPARC hacking, infrastructure improvements, previous contributions to the steering committee, loop optimizations, etc.
- Stephane Carrez for 68HC11 and 68HC12 ports.
- Steve Chamberlain for support for the Renesas SH and H8 processors and the PicoJava processor, and for GCJ config fixes.
- Glenn Chambers for help with the GCJ FAQ.
- John-Marc Chandonia for various libgcj patches.
- Denis Chertykov for contributing and maintaining the AVR port, the first GCC port for an 8-bit architecture.
- Kito Cheng for his work on the RISC-V port, including bringing up the test suite and maintenance.
- Scott Christley for his Objective-C contributions.
- Eric Christopher for his Java porting help and clean-ups.
- Branko Cibej for more warning contributions.
- The GNU Classpath project for all of their merged runtime code.
- Nick Clifton for arm, mcore, fr30, v850, m32r, msp430 rx work, `--help`, and other random hacking.
- Michael Cook for libstdc++ cleanup patches to reduce warnings.
- R. Kelley Cook for making GCC buildable from a read-only directory as well as other miscellaneous build process and documentation clean-ups.

- Ralf Corsepius for SH testing and minor bug fixing.
- François-Xavier Coudert for contributions to GNU Fortran.
- Stan Cox for care and feeding of the x86 port and lots of behind the scenes hacking.
- Alex Crain provided changes for the 3b1.
- Ian Dall for major improvements to the NS32k port.
- Paul Dale for his work to add uClinux platform support to the m68k backend.
- Palmer Dabbelt for his work maintaining the RISC-V port.
- Dario Dariol contributed the four varieties of sample programs that print a copy of their source.
- Russell Davidson for fstream and stringstream fixes in libstdc++.
- Bud Davis for work on the G77 and GNU Fortran compilers.
- Mo DeJong for GCJ and libgcj bug fixes.
- Jerry DeLisle for contributions to GNU Fortran.
- DJ Delorie for the DJGPP port, build and libiberty maintenance, various bug fixes, and the M32C, MeP, MSP430, and RL78 ports.
- Arnaud Desitter for helping to debug GNU Fortran.
- Gabriel Dos Reis for contributions to G++, contributions and maintenance of GCC diagnostics infrastructure, libstdc++-v3, including `valarray<>`, `complex<>`, maintaining the numerics library (including that pesky `<limits>` :-) and keeping up-to-date anything to do with numbers.
- Ulrich Drepper for his work on glibc, testing of GCC using glibc, ISO C99 support, CFG dumping support, etc., plus support of the C++ runtime libraries including for all kinds of C interface issues, contributing and maintaining `complex<>`, sanity checking and disbursement, configuration architecture, libio maintenance, and early math work.
- Robert J. Dubner for his work on the COBOL front end, mating the parser output to the GENERIC tree.
- François Dumont for his work on libstdc++-v3, especially maintaining and improving `debug-mode` and associative and unordered containers.
- Zdenek Dvorak for a new loop unroller and various fixes.
- Michael Eager for his work on the Xilinx MicroBlaze port.
- Richard Earnshaw for his ongoing work with the ARM.
- David Edelsohn for his direction via the steering committee, ongoing work with the RS6000/PowerPC port, help cleaning up Haifa loop changes, doing the entire AIX port of libstdc++ with his bare hands, and for ensuring GCC properly keeps working on AIX.
- Kevin Ediger for the floating point formatting of num_put::do_put in libstdc++.
- Phil Edwards for libstdc++ work including configuration hackery, documentation maintainer, chief breaker of the web pages, the occasional iostream bug fix, and work on shared library symbol versioning.
- Paul Eggert for random hacking all over GCC.
- Mark Elbrecht for various DJGPP improvements, and for libstdc++ configuration support for locales and fstream-related fixes.

- Vadim Egorov for libstdc++ fixes in strings, streambufs, and iostreams.
- Christian Ehrhardt for dealing with bug reports.
- Ben Elliston for his work to move the Objective-C runtime into its own subdirectory and for his work on autoconf.
- Revital Eres for work on the PowerPC 750CL port.
- Marc Espie for OpenBSD support.
- Doug Evans for much of the global optimization framework, arc, m32r, and SPARC work.
- Christopher Faylor for his work on the Cygwin port and for caring and feeding the gcc.gnu.org box and saving its users tons of spam.
- Fred Fish for BeOS support and Ada fixes.
- Ivan Fontes Garcia for the Portuguese translation of the GCJ FAQ.
- Peter Gerwinski for various bug fixes and the Pascal front end.
- Kaveh R. Ghazi for his direction via the steering committee, amazing work to make '`-W -Wall -W* -Werror`' useful, and testing GCC on a plethora of platforms. Kaveh extends his gratitude to the CAIP Center at Rutgers University for providing him with computing resources to work on Free Software from the late 1980s to 2010.
- John Gilmore for a donation to the FSF earmarked improving GNU Java.
- Judy Goldberg for `c++` contributions.
- Torbjorn Granlund for various fixes and the c-torture testsuite, multiply- and divide-by-constant optimization, improved long long support, improved leaf function register allocation, and his direction via the steering committee.
- Jonny Grant for improvements to `collect2's --help` documentation.
- Anthony Green for his `-Os` contributions, the moxie port, and Java front end work.
- Stu Grossman for gdb hacking, allowing GCJ developers to debug Java code.
- Michael K. Gschwind contributed the port to the PDP-11.
- Ron Guilmette implemented the `protoize` and `unprotoize` tools, the support for DWARF 1 symbolic debugging information, and much of the support for System V Release 4. He has also worked heavily on the Intel 386 and 860 support.
- Sumanth Gundapaneni for contributing the CR16 port.
- Mostafa Hagog for Swing Modulo Scheduling (SMS) and post reload GCSE.
- Bruno Haible for improvements in the runtime overhead for EH, new warnings and assorted bug fixes.
- Andrew Haley for his amazing Java compiler and library efforts.
- Chris Hanson assisted in making GCC work on HP-UX for the 9000 series 300.
- Michael Hayes for various thankless work he's done trying to get the c30/c40 ports functional. Lots of loop and unroll improvements and fixes.
- Dara Hazeghi for wading through myriads of target-specific bug reports.
- Kate Hedstrom for staking the G77 folks with an initial testsuite.
- Richard Henderson for his ongoing SPARC, alpha, ia32, and ia64 work, loop opts, and generally fixing lots of old problems we've ignored for years, flow rewrite and lots of further stuff, including reviewing tons of patches.

- Aldy Hernandez for working on the PowerPC port, SIMD support, and various fixes.
- Nobuyuki Hikichi of Software Research Associates, Tokyo, contributed the support for the Sony NEWS machine.
- Kazu Hirata for caring and feeding the Renesas H8/300 port and various fixes.
- Katherine Holcomb for work on GNU Fortran.
- Manfred Hollstein for his ongoing work to keep the m88k alive, lots of testing and bug fixing, particularly of GCC configury code.
- Steve Holmgren for MachTen patches.
- Mat Hostetter for work on the TILE-Gx and TILEPro ports.
- Jan Hubicka for his x86 port improvements.
- Falk Hueffner for working on C and optimization bug reports.
- Bernardo Innocenti for his m68k work, including merging of ColdFire improvements and uClinux support.
- Christian Iseli for various bug fixes.
- Kamil Iskra for general m68k hacking.
- Lee Iverson for random fixes and MIPS testing.
- Balaji V. Iyer for Cilk+ development and merging.
- Andreas Jaeger for testing and benchmarking of GCC and various bug fixes.
- Martin Jambor for his work on inter-procedural optimizations, the switch conversion pass, and scalar replacement of aggregates.
- Jakub Jelinek for his SPARC work and sibling call optimizations as well as lots of bug fixes and test cases, and for improving the Java build system.
- Janis Johnson for ia64 testing and fixes, her quality improvement sidetracks, and web page maintenance.
- Kean Johnston for SCO OpenServer support and various fixes.
- Tim Josling for the sample language treelang based originally on Richard Kenner's "toy" language.
- Nicolai Josuttis for additional libstdc++ documentation.
- Klaus Kaempf for his ongoing work to make alpha-vms a viable target.
- Steven G. Kargl for work on GNU Fortran.
- David Kashtan of SRI adapted GCC to VMS.
- Ryszard Kabatek for many, many libstdc++ bug fixes and optimizations of strings, especially member functions, and for auto_ptr fixes.
- Geoffrey Keating for his ongoing work to make the PPC work for GNU/Linux and his automatic regression tester.
- Brendan Kehoe for his ongoing work with G++ and for a lot of early work in just about every part of libstdc++.
- Oliver M. Kellogg of Deutsche Aerospace contributed the port to the MIL-STD-1750A.
- Richard Kenner of the New York University Ultracomputer Research Laboratory wrote the machine descriptions for the AMD 29000, the DEC Alpha, the IBM RT PC, and the IBM RS/6000 as well as the support for instruction attributes. He also made

changes to better support RISC processors including changes to common subexpression elimination, strength reduction, function calling sequence handling, and condition code support, in addition to generalizing the code for frame pointer elimination and delay slot scheduling. Richard Kenner was also the head maintainer of GCC for several years.

- Mumit Khan for various contributions to the Cygwin and Mingw32 ports and maintaining binary releases for Microsoft Windows hosts, and for massive libstdc++ porting work to Cygwin/Mingw32.
- Robin Kirkham for cpu32 support.
- Mark Klein for PA improvements.
- Thomas Koenig for various bug fixes.
- Bruce Korb for the new and improved fixincludes code.
- Benjamin Kosnik for his G++ work and for leading the libstdc++-v3 effort.
- Maxim Kuvyrkov for contributions to the instruction scheduler, the Android and m68k/Coldfire ports, and optimizations.
- Charles LaBrec contributed the support for the Integrated Solutions 68020 system.
- Asher Langton and Mike Kumbera for contributing Cray pointer support to GNU Fortran, and for other GNU Fortran improvements.
- Jeff Law for his direction via the steering committee, coordinating the entire egcs project and GCC 2.95, rolling out snapshots and releases, handling merges from GCC2, reviewing tons of patches that might have fallen through the cracks else, and random but extensive hacking.
- Walter Lee for work on the TILE-Gx and TILEPro ports.
- Marc Lehmann for his direction via the steering committee and helping with analysis and improvements of x86 performance.
- Victor Leikehman for work on GNU Fortran.
- Ted Lemon wrote parts of the RTL reader and printer.
- Kriang Lerdsuwanakij for C++ improvements including template as template parameter support, and many C++ fixes.
- Warren Levy for tremendous work on libgcj (Java Runtime Library) and random work on the Java front end.
- Alain Lichnewsky ported GCC to the MIPS CPU.
- Oskar Liljeblad for hacking on AWT and his many Java bug reports and patches.
- Robert Lipe for OpenServer support, new testsuites, testing, etc.
- Chen Liqin for various S+core related fixes/improvement, and for maintaining the S+core port.
- Martin Liska for his work on identical code folding, the sanitizers, HSA, general bug fixing and for running automated regression testing of GCC and reporting numerous bugs.
- Weiwen Liu for testing and various bug fixes.
- Manuel López-Ibáñez for improving `-Wconversion` and many other diagnostics fixes and improvements.
- Dave Love for his ongoing work with the Fortran front end and runtime libraries.

- James K. Lowden for his work on the COBOL front end, mainly the parser and CDF.
- Martin von Löwis for internal consistency checking infrastructure, various C++ improvements including namespace support, and tons of assistance with libstdc++/compiler merges.
- H.J. Lu for his previous contributions to the steering committee, many x86 bug reports, prototype patches, and keeping the GNU/Linux ports working.
- Greg McGary for random fixes and (someday) bounded pointers.
- Andrew MacLeod for his ongoing work in building a real EH system, various code generation improvements, work on the global optimizer, etc.
- Vladimir Makarov for hacking some ugly i960 problems, PowerPC hacking improvements to compile-time performance, overall knowledge and direction in the area of instruction scheduling, design and implementation of the automaton based instruction scheduler and design and implementation of the integrated and local register allocators.
- David Malcolm for his work on improving GCC diagnostics, JIT, self-tests and unit testing.
- Bob Manson for his behind the scenes work on dejagnu.
- Jose E. Marchesi for contributing the eBPF backend and his ongoing work maintaining it.
- John Marino for contributing the DragonFly BSD port.
- Philip Martin for lots of libstdc++ string and vector iterator fixes and improvements, and string clean up and testsuites.
- Dhruv Matani for work on libstdc++ allocators.
- Michael Matz for his work on dominance tree discovery, the x86-64 port, link-time optimization framework and general optimization improvements.
- All of the Mauve project contributors for Java test code.
- Bryce McKinlay for numerous GCJ and libgcj fixes and improvements.
- Adam Megacz for his work on the Microsoft Windows port of GCJ.
- Michael Meissner for LRS framework, ia32, m32r, v850, m88k, MIPS, powerpc, haifa, ECOFF debug support, and other assorted hacking.
- Jason Merrill for his direction via the steering committee and leading the G++ effort.
- Martin Michlmayr for testing GCC on several architectures using the entire Debian archive.
- David Miller for his direction via the steering committee, lots of SPARC work, improvements in jump.cc and interfacing with the Linux kernel developers.
- Gary Miller ported GCC to Charles River Data Systems machines.
- Alfred Minarik for libstdc++ string and ios bug fixes, and turning the entire libstdc++ testsuite namespace-compatible.
- Mark Mitchell for his direction via the steering committee, mountains of C++ work, load/store hoisting out of loops, alias analysis improvements, ISO C `restrict` support, and serving as release manager from 2000 to 2011.
- Alan Modra for various GNU/Linux bits and testing.

- Toon Moene for his direction via the steering committee, Fortran maintenance, and his ongoing work to make us make Fortran run fast.
- Jason Molenda for major help in the care and feeding of all the services on the gcc.gnu.org (formerly egcs.cygnus.com) machine—mail, web services, ftp services, etc etc. Doing all this work on scrap paper and the backs of envelopes would have been. . . difficult.
- Catherine Moore for fixing various ugly problems we have sent her way, including the haifa bug which was killing the Alpha & PowerPC Linux kernels.
- Mike Moreton for his various Java patches.
- David Mosberger-Tang for various Alpha improvements, and for the initial IA-64 port.
- Stephen Moshier contributed the floating point emulator that assists in cross-compilation and permits support for floating point numbers wider than 64 bits and for ISO C99 support.
- Bill Moyer for his behind the scenes work on various issues.
- Philippe De Muyter for his work on the m68k port.
- Joseph S. Myers for his work on the PDP-11 port, format checking and ISO C99 support, and continuous emphasis on (and contributions to) documentation.
- Nathan Myers for his work on libstdc++-v3: architecture and authorship through the first three snapshots, including implementation of locale infrastructure, string, shadow C headers, and the initial project documentation (DESIGN, CHECKLIST, and so forth). Later, more work on MT-safe string and shadow headers.
- Felix Natter for documentation on porting libstdc++.
- Nathanael Nerode for cleaning up the configuration/build process.
- NeXT, Inc. donated the front end that supports the Objective-C language.
- Hans-Peter Nilsson for the CRIS and MMIX ports, improvements to the search engine setup, various documentation fixes and other small fixes.
- Geoff Noer for his work on getting cygwin native builds working.
- Vegard Nossum for running automated regression testing of GCC and reporting numerous bugs.
- Diego Novillo for his work on Tree SSA, OpenMP, SPEC performance tracking web pages, GIMPLE tuples, and assorted fixes.
- David O'Brien for the FreeBSD/alpha, FreeBSD/AMD x86-64, FreeBSD/ARM, FreeBSD/PowerPC, and FreeBSD/SPARC64 ports and related infrastructure improvements.
- Alexandre Oliva for various build infrastructure improvements, scripts and amazing testing work, including keeping libtool issues sane and happy.
- Stefan Olsson for work on mt_alloc.
- Melissa O'Neill for various NeXT fixes.
- Rainer Orth for random MIPS work, including improvements to GCC's o32 ABI support, improvements to dejagnu's MIPS support, Java configuration clean-ups and porting work, and maintaining the IRIX, Solaris 2, and Tru64 UNIX ports.
- Patrick Palka for contributions to the C++ library and front end.

- Steven Pemberton for his contribution of `enquire` which allowed GCC to determine various properties of the floating point unit and generate `float.h` in older versions of GCC.
- Hartmut Penner for work on the s390 port.
- Paul Petersen wrote the machine description for the Alliant FX/8.
- Alexandre Petit-Bianco for implementing much of the Java compiler and continued Java maintainership.
- Matthias Pfaller for major improvements to the NS32k port.
- Gerald Pfeifer for his direction via the steering committee, pointing out lots of problems we need to solve, maintenance of the web pages, and taking care of documentation maintenance in general.
- Marek Polacek for his work on the C front end, the sanitizers and general bug fixing.
- Andrew Pinski for processing bug reports by the dozen, maintenance of the Objective-C runtime libraries, and many scalar optimizations.
- Ovidiu Predescu for his work on the Objective-C front end and runtime libraries.
- Jerry Quinn for major performance improvements in C++ formatted I/O.
- Ken Raeburn for various improvements to checker, MIPS ports and various cleanups in the compiler.
- Rolf W. Rasmussen for hacking on AWT.
- David Reese of Sun Microsystems contributed to the Solaris on PowerPC port.
- John Regehr for running automated regression testing of GCC and reporting numerous bugs.
- Volker Reichelt for running automated regression testing of GCC and reporting numerous bugs and for keeping up with the problem reports.
- Joern Rennecke for maintaining the sh port, loop, regmove & reload hacking and developing and maintaining the Epiphany port.
- Loren J. Rittle for improvements to libstdc++-v3 including the FreeBSD port, threading fixes, thread-related configury changes, critical threading documentation, and solutions to really tricky I/O problems, as well as keeping GCC properly working on FreeBSD and continuous testing.
- Craig Rodrigues for processing tons of bug reports.
- Ola Rönnerup for work on mt_alloc.
- Gavin Romig-Koch for lots of behind the scenes MIPS work.
- David Ronis inspired and encouraged Craig to rewrite the G77 documentation in texinfo format by contributing a first pass at a translation of the old `g77-0.5.16/f/DOC` file.
- Ken Rose for fixes to GCC's delay slot filling code.
- Ira Rosen for her contributions to the auto-vectorizer.
- Paul Rubin wrote most of the preprocessor.
- Pétur Runólfsson for major performance improvements in C++ formatted I/O and large file support in C++ filebuf.
- Chip Salzenberg for libstdc++ patches and improvements to locales, traits, Makefiles, libio, libtool hackery, and "long long" support.

- Juha Sarlin for improvements to the H8 code generator.
- Greg Satz assisted in making GCC work on HP-UX for the 9000 series 300.
- Roger Sayle for improvements to constant folding and GCC's RTL optimizers as well as for fixing numerous bugs.
- Bradley Schatz for his work on the GCJ FAQ.
- Peter Schauer wrote the code to allow debugging to work on the Alpha.
- William Schelter did most of the work on the Intel 80386 support.
- Tobias Schlüter for work on GNU Fortran.
- Bernd Schmidt for various code generation improvements and major work in the reload pass, serving as release manager for GCC 2.95.3, and work on the Blackfin and C6X ports.
- Peter Schmid for constant testing of libstdc++—especially application testing, going above and beyond what was requested for the release criteria—and libstdc++ header file tweaks.
- Jason Schroeder for jcf-dump patches.
- Andreas Schwab for his work on the m68k port.
- Lars Segerlund for work on GNU Fortran.
- Dodji Seketeli for numerous C++ bug fixes and debug info improvements.
- Tim Shen for major work on `<regex>`.
- Joel Sherrill for his direction via the steering committee, RTEMS contributions and RTEMS testing.
- Nathan Sidwell for many C++ fixes/improvements.
- Jeffrey Siegal for helping RMS with the original design of GCC, some code which handles the parse tree and RTL data structures, constant folding and help with the original VAX & m68k ports.
- Kenny Simpson for prompting libstdc++ fixes due to defect reports from the LWG (thereby keeping GCC in line with updates from the ISO).
- Franz Sirl for his ongoing work with making the PPC port stable for GNU/Linux.
- Andrey Slepuhin for assorted AIX hacking.
- Trevor Smigiel for contributing the SPU port.
- Christopher Smith did the port for Convex machines.
- Danny Smith for his major efforts on the Mingw (and Cygwin) ports. Retired from GCC maintainership August 2010, having mentored two new maintainers into the role.
- Randy Smith finished the Sun FPA support.
- Ed Smith-Rowland for his continuous work on libstdc++-v3, special functions, `<random>`, and various improvements to C++11 features.
- Scott Snyder for queue, iterator, istream, and string fixes and libstdc++ testsuite entries. Also for providing the patch to G77 to add rudimentary support for `INTEGER*1`, `INTEGER*2`, and `LOGICAL*1`.
- Zdenek Sojka for running automated regression testing of GCC and reporting numerous bugs.

- Arseny Solokha for running automated regression testing of GCC and reporting numerous bugs.
- Jayant Sonar for contributing the CR16 port.
- Brad Spencer for contributions to the GLIBCPP_FORCE_NEW technique.
- Richard Stallman, for writing the original GCC and launching the GNU project.
- Jan Stein of the Chalmers Computer Society provided support for Genix, as well as part of the 32000 machine description.
- Gerhard Steinmetz for running automated regression testing of GCC and reporting numerous bugs.
- Nigel Stephens for various mips16 related fixes/improvements.
- Jonathan Stone wrote the machine description for the Pyramid computer.
- Graham Stott for various infrastructure improvements.
- John Stracke for his Java HTTP protocol fixes.
- Mike Stump for his Elxsi port, G++ contributions over the years and more recently his vxworks contributions
- Jeff Sturm for Java porting help, bug fixes, and encouragement.
- Zhendong Su for running automated regression testing of GCC and reporting numerous bugs.
- Chengnian Sun for running automated regression testing of GCC and reporting numerous bugs.
- Shigeya Suzuki for this fixes for the bsdi platforms.
- Ian Lance Taylor for the Go frontend, the initial mips16 and mips64 support, general configury hacking, fixincludes, etc.
- Holger Teutsch provided the support for the Clipper CPU.
- Gary Thomas for his ongoing work to make the PPC work for GNU/Linux.
- Paul Thomas for contributions to GNU Fortran.
- Philipp Thomas for random bug fixes throughout the compiler
- Jason Thorpe for thread support in libstdc++ on NetBSD.
- Kresten Krab Thorup wrote the run time support for the Objective-C language and the fantastic Java bytecode interpreter.
- Michael Tiemann for random bug fixes, the first instruction scheduler, initial C++ support, function integration, NS32k, SPARC and M88k machine description work, delay slot scheduling.
- Andreas Tobler for his work porting libgcj to Darwin.
- Teemu Torma for thread safe exception handling support.
- Leonard Tower wrote parts of the parser, RTL generator, and RTL definitions, and of the VAX machine description.
- Daniel Towner and Hariharan Sandanagobalane contributed and maintain the picoChip port.
- Tom Tromey for internationalization support and for his many Java contributions and libgcj maintainership.

- Lassi Tuura for improvements to config.guess to determine HP processor types.
- Petter Urkedal for libstdc++ CXXFLAGS, math, and algorithms fixes.
- Andy Vaught for the design and initial implementation of the GNU Fortran front end.
- Brent Verner for work with the libstdc++ cshadow files and their associated configure steps.
- Todd Vierling for contributions for NetBSD ports.
- Andrew Waterman for contributing the RISC-V port, as well as maintaining it.
- Jonathan Wakely for contributing to and maintaining libstdc++.
- Dean Wakerley for converting the install documentation from HTML to texinfo in time for GCC 3.0.
- Krister Walfridsson for random bug fixes.
- Feng Wang for contributions to GNU Fortran.
- Stephen M. Webb for time and effort on making libstdc++ shadow files work with the tricky Solaris 8+ headers, and for pushing the build-time header tree. Also, for starting and driving the `<regex>` effort.
- John Wehle for various improvements for the x86 code generator, related infrastructure improvements to help x86 code generation, value range propagation and other work, WE32k port.
- Ulrich Weigand for work on the s390 port.
- Janus Weil for contributions to GNU Fortran.
- Zack Weinberg for major work on cpplib and various other bug fixes.
- Matt Welsh for help with Linux Threads support in GCJ.
- Urban Widmark for help fixing java.io.
- Mark Wielaard for new Java library code and his work integrating with Classpath.
- Dale Wiles helped port GCC to the Tahoe.
- Bob Wilson from Tensilica, Inc. for the Xtensa port.
- Jim Wilson for his direction via the steering committee, tackling hard problems in various places that nobody else wanted to work on, strength reduction and other loop optimizations.
- Paul Woegerer and Tal Agmon for the CRX port.
- Carlo Wood for various fixes.
- Tom Wood for work on the m88k port.
- Chung-Ju Wu for his work on the Andes NDS32 port.
- Canqun Yang for work on GNU Fortran.
- Masanobu Yuhara of Fujitsu Laboratories implemented the machine description for the Tron architecture (specifically, the Gmicro).
- Kevin Zachmann helped port GCC to the Tahoe.
- Ayal Zaks for Swing Modulo Scheduling (SMS).
- Qirun Zhang for running automated regression testing of GCC and reporting numerous bugs.

- Xiaoqiang Zhang for work on GNU Fortran.
- Gilles Zunino for help porting Java to Irix.

The following people are recognized for their contributions to GNAT, the Ada front end of GCC:

- Bernard Banner
- Romain Berrendonner
- Geert Bosch
- Emmanuel Briot
- Joel Brobecker
- Ben Brosgol
- Vincent Celier
- Arnaud Charlet
- Chien Chieng
- Cyrille Comar
- Cyrille Crozes
- Robert Dewar
- Gary Dismukes
- Robert Duff
- Ed Falis
- Ramon Fernandez
- Sam Figueroa
- Vasiliy Fofanov
- Michael Friess
- Franco Gasperoni
- Ted Giering
- Matthew Gingell
- Laurent Guerby
- Jerome Guitton
- Olivier Hainque
- Jerome Hugues
- Hristian Kirtchev
- Jerome Lambourg
- Bruno Leclerc
- Albert Lee
- Sean McNeil
- Javier Miranda
- Laurent Nana
- Pascal Obry
- Dong-Ik Oh

- Laurent Pautet
- Brett Porter
- Thomas Quinot
- Nicolas Roche
- Pat Rogers
- Jose Ruiz
- Douglas Rupp
- Sergey Rybin
- Gail Schenker
- Ed Schonberg
- Nicolas Setton
- Samuel Tardieu

The following people are recognized for their contributions of new features, bug reports, testing and integration of classpath/libgcj for GCC version 4.1:

- Lillian Angel for `JTree` implementation and lots Free Swing additions and bug fixes.
- Wolfgang Baer for `GapContent` bug fixes.
- Anthony Balkissoon for `JList`, Free Swing 1.5 updates and mouse event fixes, lots of Free Swing work including `JTable` editing.
- Stuart Ballard for RMI constant fixes.
- Goffredo Baroncelli for `HTTPURLConnection` fixes.
- Gary Benson for `MessageFormat` fixes.
- Daniel Bonniot for `Serialization` fixes.
- Chris Burdess for lots of gnu.xml and http protocol fixes, `StAX` and `DOM` `xml:id` support.
- Ka-Hing Cheung for `TreePath` and `TreeSelection` fixes.
- Archie Cobbs for build fixes, VM interface updates, `URLClassLoader` updates.
- Kelley Cook for build fixes.
- Martin Cordova for Suggestions for better `SocketTimeoutException`.
- David Daney for `BitSet` bug fixes, `HttpURLConnection` rewrite and improvements.
- Thomas Fitzsimmons for lots of upgrades to the gtk+ AWT and Cairo 2D support. Lots of imageio framework additions, lots of AWT and Free Swing bug fixes.
- Jeroen Frijters for `ClassLoader` and nio cleanups, serialization fixes, better `Proxy` support, bug fixes and IKVM integration.
- Santiago Gala for `AccessControlContext` fixes.
- Nicolas Geoffray for `VMClassLoader` and `AccessController` improvements.
- David Gilbert for `basic` and `metal` icon and plaf support and lots of documenting, Lots of Free Swing and metal theme additions. `MetalIconFactory` implementation.
- Anthony Green for `MIDI` framework, `ALSA` and `DSSI` providers.
- Andrew Haley for `Serialization` and `URLClassLoader` fixes, gcj build speedups.
- Kim Ho for `JFileChooser` implementation.

- Andrew John Hughes for `Locale` and net fixes, URI RFC2986 updates, `Serialization` fixes, `Properties` XML support and generic branch work, VMIntegration guide update.
- Bastiaan Huisman for `TimeZone` bug fixing.
- Andreas Jaeger for mprec updates.
- Paul Jenner for better `-Werror` support.
- Ito Kazumitsu for `NetworkInterface` implementation and updates.
- Roman Kennke for `BoxLayout`, `GrayFilter` and `SplitPane`, plus bug fixes all over. Lots of Free Swing work including styled text.
- Simon Kitching for `String` cleanups and optimization suggestions.
- Michael Koch for configuration fixes, `Locale` updates, bug and build fixes.
- Guilhem Lavaux for configuration, thread and channel fixes and Kaffe integration. JCL native `Pointer` updates. Logger bug fixes.
- David Lichteblau for JCL support library global/local reference cleanups.
- Aaron Luchko for JDWP updates and documentation fixes.
- Ziga Mahkovec for `Graphics2D` upgraded to Cairo 0.5 and new regex features.
- Sven de Marothy for BMP imageio support, CSS and `TextLayout` fixes. `GtkImage` rewrite, 2D, awt, free swing and date/time fixes and implementing the Qt4 peers.
- Casey Marshall for crypto algorithm fixes, `FileChannel` lock, `SystemLogger` and `FileHandler` rotate implementations, NIO `FileChannel.map` support, security and policy updates.
- Bryce McKinlay for RMI work.
- Audrius Meskauskas for lots of Free Corba, RMI and HTML work plus testing and documenting.
- Kalle Olavi Niemitalo for build fixes.
- Rainer Orth for build fixes.
- Andrew Overholt for `File` locking fixes.
- Ingo Proetel for `Image`, `Logger` and `URLClassLoader` updates.
- Olga Rodimina for `MenuSelectionManager` implementation.
- Jan Roehrich for `BasicTreeUI` and `JTree` fixes.
- Julian Scheid for documentation updates and gjdoc support.
- Christian Schlichtherle for zip fixes and cleanups.
- Robert Schuster for documentation updates and beans fixes, `TreeNode` enumerations and `ActionCommand` and various fixes, XML and URL, AWT and Free Swing bug fixes.
- Keith Seitz for lots of JDWP work.
- Christian Thalinger for 64-bit cleanups, Configuration and VM interface fixes and `CACAO` integration, `fdlibm` updates.
- Gael Thomas for `VMClassLoader` boot packages support suggestions.
- Andreas Tobler for Darwin and Solaris testing and fixing, `Qt4` support for Darwin / macOS, `Graphics2D` support, `gtk+` updates.
- Dalibor Topic for better `DEBUG` support, build cleanups and Kaffe integration. `Qt4` build infrastructure, `SHA1PRNG` and `GdkPixbugDecoder` updates.

- Tom Tromey for Eclipse integration, generics work, lots of bug fixes and gcj integration including coordinating The Big Merge.
- Mark Wielaard for bug fixes, packaging and release management, `Clipboard` implementation, system call interrupts and network timeouts and `GdkPixpufDecoder` fixes.

In addition to the above, all of which also contributed time and energy in testing GCC, we would like to thank the following for their contributions to testing:

- Michael Abd-El-Malek
- Thomas Arend
- Bonzo Armstrong
- Steven Ashe
- Chris Baldwin
- David Billinghurst
- Jim Blandy
- Stephane Bortzmeyer
- Horst von Brand
- Frank Braun
- Rodney Brown
- Sidney Cadot
- Bradford Castalia
- Robert Clark
- Jonathan Corbet
- Ralph Doncaster
- Richard Emberson
- Levente Farkas
- Graham Fawcett
- Mark Fernyhough
- Robert A. French
- Jörgen Freyh
- Mark K. Gardner
- Charles-Antoine Gauthier
- Yung Shing Gene
- David Gilbert
- Simon Gornall
- Fred Gray
- John Griffin
- Patrik Hagglund
- Phil Hargett
- Amancio Hasty
- Takafumi Hayashi

- Bryan W. Headley
- Kevin B. Hendricks
- Joep Jansen
- Christian Joensson
- Michel Kern
- David Kidd
- Tobias Kuipers
- Anand Krishnaswamy
- A. O. V. Le Blanc
- llewelly
- Damon Love
- Brad Lucier
- Matthias Klose
- Martin Knoblauch
- Rick Lutowski
- Jesse Macnish
- Stefan Morrell
- Anon A. Mous
- Matthias Mueller
- Pekka Nikander
- Rick Niles
- Jon Olson
- Magnus Persson
- Chris Pollard
- Richard Polton
- Derk Reefman
- David Rees
- Paul Reilly
- Tom Reilly
- Torsten Rueger
- Danny Sadinoff
- Marc Schifer
- Erik Schnetter
- Wayne K. Schroll
- David Schuler
- Vin Shelton
- Tim Souder
- Adam Sulmicki
- Bill Thorson

- George Talbot
- Pedro A. M. Vazquez
- Gregory Warnes
- Ian Watson
- David E. Young
- And many others

And finally we'd like to thank everyone who uses the compiler, provides feedback and generally reminds us why we're doing this work in the first place.

Appendix A Indices

A.1 Option Index

GCC's command line options are indexed here without any initial '-' or '--'. Where an option has both positive and negative forms (such as -f*option* and -fno-*option*), relevant entries in the manual are indexed under the most appropriate form; it may sometimes be useful to look up both forms.

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