

# The GNU Modula-2 Compiler

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For GCC version 16.0.0 (pre-release)

(GCC)

Gaius Mulley

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Published by the Free Software Foundation  
51 Franklin Street, Fifth Floor  
Boston, MA 02110-1301, USA

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# 1 Overview of GNU Modula-2

## 1.1 What is GNU Modula-2

GNU Modula-2 is a front end (<https://gcc.gnu.org/frontends.html>) for the GNU Compiler Collection (GCC (<https://gcc.gnu.org>)). The GNU Modula-2 compiler is compliant with the PIM2, PIM3, PIM4 and ISO dialects. Also implemented are a complete set of free ISO libraries and PIM libraries.

1

## 1.2 Why use GNU Modula-2

There are a number of advantages of using GNU Modula-2 rather than translate an existing project into another language.

The first advantage is of maintainability of the original sources and the ability to debug the original project source code using a combination of gm2 and gdb.

The second advantage is that gcc runs on many processors and platforms. gm2 builds and runs on powerpc64le, amd64, i386, aarch64 to name but a few processors.

gm2 can produce swig interface headers to allow access from Python and other scripting languages. It can also be used with C/C++ and generate shared libraries.

The compiler provides semantic analysis and run time checking (full ISO Modula-2 checking is implemented) and there is a plugin which can, under certain conditions, detect run time errors at compile time.

The compiler supports PIM2, PIM3, PIM4 and ISO dialects of Modula-2, work is underway to implement M2R10. Many of the GCC builtins are available and access to assembly programming is achieved using the same syntax as that used by GCC.

The gm2 driver allows third party libraries to be installed alongside gm2 libraries. See Section 2.7 [Module Search Path], page 19.

## 1.3 How to get source code using git

GNU Modula-2 is now in the GCC git tree (<https://gcc.gnu.org/git.html>).

## 1.4 GNU Modula-2 Features

- the compiler currently complies with Programming in Modula-2 Edition 2, 3, 4 and ISO Modula-2. Users can switch on specific language features by using: ‘-fpim’, ‘-fpim2’, ‘-fpim3’, ‘-fpim4’ or ‘-fiso’.

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<sup>1</sup> The four Modula-2 dialects supported are defined in the following references:

PIM2: ‘Programming in Modula-2’, 2nd Edition, Springer Verlag, 1982, 1983 by Niklaus Wirth (PIM2).

PIM3: ‘Programming in Modula-2’, 3rd Corrected Edition, Springer Verlag, 1985 (PIM3).

PIM4: ‘Programming in Modula-2’, 4th Edition, Springer Verlag, 1988 (PIM4 (<https://freepages.modula2.org/report4/modula-2.html>)).

ISO: the ISO Modula-2 language as defined in ‘ISO/IEC Information technology - programming languages - part 1: Modula-2 Language, ISO/IEC 10514-1 (1996)’

- the option ‘`-fswig`’ will automatically create a swig interface file which corresponds to the definition module of the file being compiled.
- exception handling is compatible with C++ and swig. Modula-2 code can be used with C or C++ code.
- Python can call GNU Modula-2 modules via swig.
- shared libraries can be built.
- fixed sized types are now available from ‘SYSTEM’.
- variables can be declared at addresses.
- much better dwarf-2 debugging support and when used with ‘gdb’ the programmer can display RECORDs, ARRAYs, SETs, subranges and constant char literals in Modula-2 syntax.
- supports sets of any ordinal size (memory permitting).
- easy interface to C, and varargs can be passed to C routines.
- many Logitech libraries have been implemented and can be accessed via: ‘`-flibs=m2log,m2pim,m2iso`’.
- coroutines have been implemented in the PIM style and these are accessible from SYSTEM. A number of supporting libraries (executive and file descriptor mapping to interrupt vector libraries are available through the ‘`-flibs=m2iso,m2pim`’ switch).
- can be built as a cross compiler (for embedded microprocessors such as the AVR and the ARM).

## 2 Using GNU Modula-2

This document contains the user and design issues relevant to the Modula-2 front end to gcc.

### 2.1 Example compile and link

The `gm2` command is the GNU compiler for the Modula-2 language and supports many of the same options as `gcc`. See Section “Option Summary” in *Using the GNU Compiler Collection (GCC)*. This manual only documents the options specific to `gm2`.

This section describes how to compile and link a simple hello world program. It provides a few examples of using the different options mentioned in see Section 2.2 [Compiler options], page 3. Assuming that you have a file called `hello.mod` in your current directory which contains:

```
MODULE hello ;

FROM StrIO IMPORT WriteString, WriteLn ;

BEGIN
  WriteString ('hello world') ; WriteLn
END hello.
```

You can compile and link it by: `gm2 -g hello.mod`. The result will be an `a.out` file created in your directory.

You can split this command into two steps if you prefer. The compile step can be achieved by: `gm2 -g -c -fscaffold-main hello.mod` and the link via: `gm2 -g hello.o`.

<sup>1</sup>

### 2.2 Compiler options

This section describes the compiler options specific to GNU Modula-2 for generic flags details See Section “Invoking GCC” in `gcc`.

For any given input file, the file name suffix determines what kind of compilation is done. The following kinds of input file names are supported:

- file.mod** Modula-2 implementation or program source files. See the `-fmod=` option if you wish to compile a project which uses a different source file extension.
- file.def** Modula-2 definition module source files. Definition modules are not compiled separately, in GNU Modula-2 definition modules are parsed as required when program or implementation modules are compiled. See the `-fdef=` option if you wish to compile a project which uses a different source file extension.

---

<sup>1</sup> To see all the compile actions taken by `gm2` users can also add the `-v` flag at the command line, for example:

```
gm2 -v -g -I. hello.mod
```

This displays the sub processes initiated by `gm2` which can be useful when trouble shooting.

You can specify more than one input file on the `gm2` command line,

- `-g`            create debugging information so that debuggers such as `gdb` can inspect and control executable.
- `-I`            used to specify the search path for definition and implementation modules. An example is: `gm2 -g -c -I:../libs foo.mod`. If this option is not specified then the default path is added which consists of the current directory followed by the appropriate language dialect library directories.
- `-fauto-init`       turns on auto initialization of pointers to NIL. Whenever a block is created all pointers declared within this scope will have their addresses assigned to NIL.
- `-fbounds`       turns on run time subrange, array index and indirection via NIL pointer checking.
- `-fcase`        turns on compile time checking to check whether a `CASE` statement requires an `ELSE` clause when one was not specified.
- `-fcpp`        preprocess the source with '`cpp -lang-asm -traditional-cpp`'. For further details about these options See Section "Invocation" in `cpp`. If '`-fcpp`' is supplied then all definition modules and implementation modules which are parsed will be preprocessed by '`cpp`'.
- `-fdebug-builtins`   call a real function, rather than the builtin equivalent. This can be useful for debugging parameter values to a builtin function as it allows users to single step code into an intrinsic function.
- `-fdef=`        recognize the specified suffix as a definition module filename. The default implementation and module filename suffix is `.def`. If this option is used GNU Modula-2 will still fall back to this default if a requested definition module is not found.
- `-fdump-system-exports`   display all inbuilt system items. This is an internal command line option.
- `-fexceptions`     turn on exception handling code. By default this option is on. Exception handling can be disabled by '`-fno-exceptions`' and no references are made to the run time exception libraries.
- `-fextended-opaque`   allows opaque types to be implemented as any type. This is a GNU Modula-2 extension and it requires that the implementation module defining the opaque type is available so that it can be resolved when compiling the module which imports the opaque type.
- `-ffloatvalue`     turns on run time checking to check whether a floating point number is about to exceed range.

- fgen-module-list=filename**  
attempt to find all modules when linking and generate a module list. If the **filename** is '-' then the contents are not written and only used to force the linking of all module ctors. This option cannot be used if '-fuse-list=' is enabled.
- findex** generate code to check whether array index values are out of bounds. Array index checking can be disabled via '-fno-index'.
- fiso** turn on ISO standard features. Currently this enables the ISO **SYSTEM** module and alters the default library search path so that the ISO libraries are searched before the PIM libraries. It also effects the behavior of **DIV** and **MOD** operators. See Section 2.6 [Dialect], page 18.
- flibs=** modifies the default library search path. The libraries supplied are: m2pim, m2iso, m2min, m2log and m2cor. These map onto the Programming in Modula-2 base libraries, ISO standard libraries, minimal library support, Logitech compatible library and Programming in Modula-2 with coroutines. Multiple libraries can be specified and are comma separated with precedence going to the first in the list. It is not necessary to use -flibs=m2pim or -flibs=m2iso if you also specify -fpim, -fpim2, -fpim3, -fpim4 or -fiso. Unless you are using -flibs=m2min you should include m2pim as they provide the base modules which all other dialects utilize. The option '-fno-libs=-' disables the 'gm2' driver from modifying the search and library paths.
- static-libgm2**  
On systems that provide the m2 runtimes as both shared and static libraries, this option forces the use of the static version.
- fm2-debug-trace=**  
turn on trace debugging using a comma separated list: 'line,token,quad,all'. This is an internal command line option.
- fm2-dump=**  
enable dumping of modula-2 internal representation of data structures using a comma separated list. The list can contain: 'quad,gimple,decl,all'.
- fm2-dump-decl=filestem**  
dump the modula-2 representation of a symbol to the **filestem** specified. This option only takes effect if the '-fm2-dump-filter' is specified.
- fm2-dump-gimple=filestem**  
dump modula-2 gimple representation to the **filestem** specified.
- fm2-dump-quad=filestem**  
dump quadruple representation to the **filestem** specified.
- fm2-dump-filter='rules'**  
filter the language dumps '-fdump-lang-decl', '-fdump-lang-gimple' and '-fdump-lang-quad' on 'rules'. 'rules' must be a comma separated list which can take three forms: the full decl textual name of a procedure, '[libname.]module.ident' or '[filename:]module.ident'. This is an

internal command line option. Currently it only filters on procedure names and regexp matching is not implemented. Three examples of its use following the previous forms could be: `-fm2-dump-filter=_M2_hello_init`, `-fm2-dump-filter=m2pim.StrIO.WriteString` and `-fm2-dump-filter=StrLib.mod:StrIO.WriteString`.

- `-fm2-file-offset-bits=`  
force the type `SYSTEM.COFF_T` to be built using the specified number of bits. If this option is not used then default is `CSSIZE_T` bits.
- `-fm2-g` improve the debugging experience for new programmers at the expense of generating `nop` instructions if necessary to ensure single stepping precision over all code related keywords. An example of this is in termination of a list of nested `IF` statements where multiple `END` keywords are mapped onto a sequence of `nop` instructions.
- `-fm2-lower-case`  
render keywords in error messages using lower case.
- `-fm2-pathname=`  
specify the module mangled prefix name for all modules in the following include paths.
- `-fm2-pathnameI`  
for internal use only: used by the driver to copy the user facing ‘`-I`’ option.
- `-fm2-pathname-root=pathroot`  
add search paths derived from the specified `pathroot`. See Section 2.7 [Module Search Path], page 19, for examples.
- `-fm2-pathname-rootI`  
for internal use only: used by the driver to copy every user ‘`-fm2-pathname-root=`’ facing option in order with all other ‘`-I`’ options.
- `-fm2-plugin`  
insert plugin to identify run time errors at compile time (default on).
- `-fm2-prefix=`  
specify the module mangled prefix name. All exported symbols from a definition module will have the prefix name.
- `-fm2-statistics`  
generates quadruple information: number of quadruples generated, number of quadruples remaining after optimization and number of source lines compiled.
- `-fm2-strict-type`  
experimental flag to turn on the new strict type checker.
- `-fm2-strict-type-reason`  
provides more detail why the types are incompatible.
- `-fm2-whole-program`  
compile all implementation modules and program module at once. Notice that you need to take care if you are compiling different dialect modules (particu-

larly with the negative operands to modulus). But this option, when coupled together with `-O3`, can deliver huge performance improvements.

- `-fmod=` recognize the specified suffix as implementation and module filenames. The default implementation and module filename suffix is `.mod`. If this option is used GNU Modula-2 will still fall back to this default if it needs to read an implementation module and the specified suffixed filename does not exist.
- `-fnil` generate code to detect accessing data through a NIL value pointer. Dereferencing checking through a NIL pointer can be disabled by `'-fno-nil'`.
- `-fpim` turn on PIM standard features. Currently this enables the PIM `SYSTEM` module and determines which identifiers are pervasive (declared in the base module). If no other `'-fpim[234]'` switch is used then division and modulus operators behave as defined in PIM4. See Section 2.6 [Dialect], page 18.
- `-fpim2` turn on PIM-2 standard features. Currently this removes `SIZE` from being a pervasive identifier (declared in the base module). It places `SIZE` in the `SYSTEM` module. It also effects the behavior of `DIV` and `MOD` operators. See Section 2.6 [Dialect], page 18.
- `-fpim3` turn on PIM-3 standard features. Currently this only effects the behavior of `DIV` and `MOD` operators. See Section 2.6 [Dialect], page 18.
- `-fpim4` turn on PIM-4 standard features. Currently this only effects the behavior of `DIV` and `MOD` operators. See Section 2.6 [Dialect], page 18.
- `-fpositive-mod-floor-div`  
forces the `DIV` and `MOD` operators to behave as defined by PIM4. All modulus results are positive and the results from the division are rounded to the floor. See Section 2.6 [Dialect], page 18.
- `-fpthread`  
link against the pthread library. By default this option is on. It can be disabled by `'-fno-pthread'`. GNU Modula-2 uses the GCC pthread libraries to implement coroutines (see the `SYSTEM` implementation module).
- `-frange` generate code to check the assignment range, return value range set range and constructor range. Range checking can be disabled via `'-fno-range'`.
- `-freturn` generate code to check that functions always exit with a `RETURN` and do not fall out at the end. Return checking can be disabled via `'-fno-return'`.
- `-fruntime-modules=`  
specify, using a comma separated list, the run time modules and their order. These modules will initialized first before any other modules in the application dependency. By default the run time modules list is set to `m2iso:RTentity,m2iso:Storage,m2iso:SYSTEM,m2iso:M2RTS,m2iso:RTExceptions,m2iso:IOLink`. Note that these modules will only be linked into your executable if they are required. Adding a long list of dependent modules will not effect the size of the executable it merely states the initialization order should they be required.

- fscaffold-dynamic**  
the option ensures that ‘gm2’ will generate a dynamic scaffold infrastructure when compiling implementation and program modules. By default this option is on. Use ‘-fno-scaffold-dynamic’ to turn it off or select ‘-fno-scaffold-static’.
- fscaffold-c**  
generate a C source scaffold for the current module being compiled.
- fscaffold-c++**  
generate a C++ source scaffold for the current module being compiled.
- fscaffold-main**  
force the generation of the ‘main’ function. This is not necessary if the ‘-c’ is omitted.
- fscaffold-static**  
the option ensures that ‘gm2’ will generate a static scaffold within the program module. The static scaffold consists of sequences of calls to all dependent module initialization and finalization procedures. The static scaffold is useful for debugging and single stepping the initialization blocks of implementation modules.
- fshared** generate a shared library from the module.
- fsoft-check-all**  
turns on all run time checks. This is the same as invoking GNU Modula-2 using the command options **-fnil -frange -findex -fwholevalue -fwholediv -fcase -freturn**.
- fsources**  
displays the path to the source of each module. This option can be used at compile time to check the correct definition module is being used.
- fswig** generate a swig interface file.
- funbounded-by-reference**  
enable optimization of unbounded parameters by attempting to pass non **VAR** unbounded parameters by reference. This optimization avoids the implicit copy inside the callee procedure. GNU Modula-2 will only allow unbounded parameters to be passed by reference if, inside the callee procedure, they are not written to, no address is calculated on the array and it is not passed as a **VAR** parameter. Note that it is possible to write code to break this optimization, therefore this option should be used carefully. For example it would be possible to take the address of an array, pass the address and the array to a procedure, read from the array in the procedure and write to the location using the address parameter.  
Due to the dangerous nature of this option it is not enabled when the ‘-O’ option is specified.
- fuse-list=filename**  
if ‘-fscaffold-static’ is enabled then use the file **filename** for the initialization order of modules. Whereas if ‘-fscaffold-dynamic’ is enabled then

use this file to force linking of all module ctors. This option cannot be used if `'-fgen-module-list='` is enabled.

**-fwholediv**

generate code to detect whole number division by zero or modulus by zero.

**-fwholevalue**

generate code to detect whole number overflow and underflow.

**-Wcase-enum**

generate a warning if a **CASE** statement selects on an enumerated type expression and the statement is missing one or more **CASE** labels. No warning is issued if the **CASE** statement has a default **ELSE** clause. The option `'-Wall'` will turn on this flag.

**-Wuninit-variable-checking**

issue a warning if a variable is used before it is initialized. The checking only occurs in the first basic block in each procedure. It does not check parameters, array types or set types.

**-Wuninit-variable-checking=all,known,cond**

issue a warning if a variable is used before it is initialized. The checking will only occur in the first basic block in each procedure if `'known'` is specified. If `'cond'` or `'all'` is specified then checking continues into conditional branches of the flow graph. All checking will stop when a procedure call is invoked or the top of a loop is encountered. The option `'-Wall'` will turn on this flag with `'-Wuninit-variable-checking=known'`. The `'-Wuninit-variable-checking=all'` will increase compile time.

**-fwideset**

turn on access to the runtime support library module `'M2WIDSET'`. By default this option is on. Wideset provision can be disabled by `'-fno-wideset'` and no reference will be made to the run time `'M2WIDSET'` library.

This section describes the linking related options. There are three linking strategies available which are dynamic scaffold, static scaffold and user defined. The dynamic scaffold is enabled by default and each module will register itself to the run time `'M2RTS'` via a constructor. The static scaffold mechanism will invoke each modules `'_init'` and `'_finish'` function in turn via a sequence of calls from within `'main'`. Lastly the user defined strategy can be implemented by turning off the dynamic and static options via `'-fno-scaffold-dynamic'` and `'-fno-scaffold-static'`.

In the simple test below:

```
$ gm2 hello.mod
```

the driver will add the options `'-fscaffold-dynamic'` and `'-fgen-module-list=--'` which generate a list of application modules and also creates the `'main'` function with calls to `'M2RTS'`. It can be useful to add the option `'-fsources'` which displays the source files as they are parsed and summarizes whether the source file is required for compilation or linking.

If you wish to split the above command line into a compile and link then you could use these steps:

```
$ gm2 -c -fscaffold-main hello.mod
```

```
$ gm2 hello.o
```

The `-fscaffold-main` informs the compiler to generate the `'main'` function and scaffold. You can enable the environment variable `'GCC_M2LINK_RTFLAG'` to trace the construction and destruction of the application. The values for `'GCC_M2LINK_RTFLAG'` are shown in the table below:

value	meaning
=====	
<code>all</code>	turn on all flags below
<code>module</code>	trace modules as they register themselves
<code>hex</code>	display the hex address of the init/fini functions
<code>warning</code>	show any warnings
<code>pre</code>	generate module list prior to dependency resolution
<code>dep</code>	trace module dependency resolution
<code>post</code>	generate module list after dependency resolution
<code>force</code>	generate a module list after dependency and forced ordering is complete

The values can be combined using a comma separated list.

One of the advantages of the dynamic scaffold is that the driver behaves in a similar way to the other front end drivers. For example consider a small project consisting of 4 definition implementation modules (`'a.def'`, `'a.mod'`, `'b.def'`, `'b.mod'`, `'c.def'`, `'c.mod'`, `'d.def'`, `'d.mod'`) and a program module `'program.mod'`.

To link this project we could:

```
$ gm2 -g -c a.mod
$ gm2 -g -c b.mod
$ gm2 -g -c c.mod
$ gm2 -g -c d.mod
$ gm2 -g program.mod a.o b.o c.o d.o
```

The module initialization sequence is defined by the ISO standard to follow the import graph traversal. The initialization order is the order in which the corresponding separate modules finish the processing of their import lists.

However, if required, you can override this using `'-fruntime-modules=a,b,c,d'` for example which forces the initialization sequence to `'a'`, `'b'`, `'c'` and `'d'`.

## 2.3 Elementary data types

This section describes the elementary data types supported by GNU Modula-2. It also describes the relationship between these data types and the equivalent C data types.

The following data types are supported: `INTEGER`, `LONGINT`, `SHORTINT`, `CARDINAL`, `LONGCARD`, `SHORTCARD`, `BOOLEAN`, `REAL`, `LONGREAL`, `SHORTREAL`, `COMPLEX`, `LONGCOMPLEX`, `SHORTCOMPLEX` and `CHAR`.

An equivalence table is given below:

GNU Modula-2	GNU C
=====	
<code>INTEGER</code>	<code>int</code>
<code>LONGINT</code>	<code>long long int</code>

SHORTINT	short int
CARDINAL	unsigned int
LONGCARD	long long unsigned int
SHORTCARD	short unsigned int
BOOLEAN	bool
REAL	double
LONGREAL	long double
SHORTREAL	float
CHAR	char
SHORTCOMPLEX	complex float
COMPLEX	complex double
LONGCOMPLEX	complex long double

Note that GNU Modula-2 also supports fixed sized data types which are exported from the `SYSTEM` module. See Section 2.22 [The PIM system module], page 52. See Section 2.23 [The ISO system module], page 56.

## 2.4 Permanently accessible base procedures.

This section describes the procedures and functions which are always visible.

### 2.4.1 Standard procedures and functions common to PIM and ISO

The following procedures are implemented and conform with Programming in Modula-2 and ISO Modula-2: `NEW`, `DISPOSE`, `INC`, `DEC`, `INCL`, `EXCL` and `HALT`. The standard functions are: `ABS`, `CAP`, `CHR`, `FLOAT`, `HIGH`, `LFLOAT`, `LTRUNC`, `MIN`, `MAX`, `ODD`, `SFLOAT`, `STRUNC` `TRUNC` and `VAL`. All these functions and procedures (except `HALT`, `NEW`, `DISPOSE` and, under non constant conditions, `LENGTH`) generate in-line code for efficiency.

```
(*
  ABS - returns the positive value of i.
*)
```

```
PROCEDURE ABS (i: <any signed type>) : <any signed type> ;
```

```
(*
  CAP - returns the capital of character ch providing
        ch lies within the range 'a'..'z'. Otherwise ch
        is returned unaltered.
*)
```

```
PROCEDURE CAP (ch: CHAR) : CHAR ;
```

```
(*
  CHR - converts a value of a <whole number type> into a CHAR.
```

```

        CHR(x) is shorthand for VAL(CHAR, x).
*)

PROCEDURE CHR (x: <whole number type>) : CHAR ;

(*
    DISPOSE - the procedure DISPOSE is replaced by:
               DEALLOCATE(p, TSIZE(p^)) ;
    The user is expected to import the procedure DEALLOCATE
    (normally found in the module, Storage.)

    In:  a variable p: of any pointer type which has been
          initialized by a call to NEW.
    Out: the area of memory
          holding p^ is returned to the system.
    Note that the underlying procedure DEALLOCATE
          procedure in module Storage will assign p to NIL.
*)

PROCEDURE DISPOSE (VAR p:<any pointer type>) ;

(*
    DEC - can either take one or two parameters.  If supplied
           with one parameter then on the completion of the call to
           DEC, v will have its predecessor value.  If two
           parameters are supplied then the value v will have its
           n'th predecessor.  For these reasons the value of n
           must be >=0.
*)

PROCEDURE DEC (VAR v: <any base type>; [n: <any base type> = 1]) ;

(*
    EXCL - excludes bit element e from a set type s.
*)

PROCEDURE EXCL (VAR s: <any set type>; e: <element of set type s>) ;

(*
    FLOAT - will return a REAL number whose value is the same as o.
*)

PROCEDURE FLOAT (o: <any whole number type>) : REAL ;

(*

```

```

    FLOATS - will return a SHORTREAL number whose value is the same as o.
*)

```

```

PROCEDURE FLOATS (o: <any whole number type>) : REAL ;

```

```

(*)
    FLOATL - will return a LONGREAL number whose value is the same as o.
*)

```

```

PROCEDURE FLOATL (o: <any whole number type>) : REAL ;

```

```

(*)
    HALT - will call the HALT procedure inside the module M2RTS.
           Users can replace M2RTS.
*)

```

```

PROCEDURE HALT ;

```

```

(*)
    HIGH - returns the last accessible index of an parameter declared as
           ARRAY OF CHAR. Thus

```

```

    PROCEDURE foo (a: ARRAY OF CHAR) ;
    VAR
        c: CARDINAL ;
    BEGIN
        c := HIGH(a)
    END foo ;

```

```

    BEGIN
        foo('hello')
    END

```

```

    will cause the local variable c to contain the value 5
*)

```

```

PROCEDURE HIGH (a: ARRAY OF CHAR) : CARDINAL ;

```

```

(*)
    INC - can either take one or two parameters. If supplied
          with one parameter then on the completion of the call to
          INC, v will have its successor value. If two
          parameters are supplied then the value v will have its
          n'th successor. For these reasons the value of n
          must be >=0.

```

```

*)

```

```

PROCEDURE INC (VAR v: <any base type>; [n: <any base type> = 1]) ;

(*
  INCL - includes bit element e to a set type s.
*)

PROCEDURE INCL (VAR s: <any set type>; e: <element of set type s>) ;

(*
  LFLOAT - will return a LONGREAL number whose value is the same as o.
*)

PROCEDURE LFLOAT (o: <any whole number type>) : LONGREAL ;

(*
  LTRUNC - will return a LONG<type> number whose value is the
           same as o. PIM2, PIM3 and ISO Modula-2 will return
           a LONGCARD whereas PIM4 returns LONGINT.
*)

PROCEDURE LTRUNC (o: <any floating point type>) : LONG<type> ;

(*
  MIN - returns the lowest legal value of an ordinal type.
*)

PROCEDURE MIN (t: <ordinal type>) : <ordinal type> ;

(*
  MAX - returns the largest legal value of an ordinal type.
*)

PROCEDURE MAX (t: <ordinal type>) : <ordinal type> ;

(*
  NEW - the procedure NEW is replaced by:
        ALLOCATE(p, TSIZE(p^)) ;
        The user is expected to import the procedure ALLOCATE
        (normally found in the module, Storage.)

        In:  a variable p: of any pointer type.
        Out: variable p is set to some allocated memory

```

```

        which is large enough to hold all the contents of p^.
*)

PROCEDURE NEW (VAR p:<any pointer type>) ;

(*
    ODD - returns TRUE if the value is not divisible by 2.
*)

PROCEDURE ODD (x: <whole number type>) : BOOLEAN ;

(*
    SFLOAT - will return a SHORTREAL number whose value is the same
              as o.
*)

PROCEDURE SFLOAT (o: <any whole number type>) : SHORTREAL ;

(*
    STRUNC - will return a SHORT<type> number whose value is the same
              as o.  PIM2, PIM3 and ISO Modula-2 will return a
              SHORTCARD whereas PIM4 returns SHORTINT.
*)

PROCEDURE STRUNC (o: <any floating point type>) : SHORT<type> ;

(*
    TRUNC - will return a <type> number whose value is the same as o.
            PIM2, PIM3 and ISO Modula-2 will return a CARDINAL
            whereas PIM4 returns INTEGER.
*)

PROCEDURE TRUNC (o: <any floating point type>) : <type> ;

(*
    TRUNCS - will return a <type> number whose value is the same
              as o.  PIM2, PIM3 and ISO Modula-2 will return a
              SHORTCARD whereas PIM4 returns SHORTINT.
*)

PROCEDURE TRUNCS (o: <any floating point type>) : <type> ;

(*
    TRUNCL - will return a <type> number whose value is the same

```

```

        as o. PIM2, PIM3 and ISO Modula-2 will return a
        LONGCARD whereas PIM4 returns LONGINT.
*)

PROCEDURE TRUNCL (o: <any floating point type>) : <type> ;

(*
    VAL - converts data i of <any simple data type 2> to
          <any simple data type 1> and returns this value.
          No range checking is performed during this conversion.
*)

PROCEDURE VAL (<any simple data type 1>,
               i: <any simple data type 2>) : <any simple data type 1> ;

```

### 2.4.2 ISO specific standard procedures and functions

The standard function `LENGTH` is specific to ISO Modula-2 and is defined as:

```

(*
    IM - returns the imaginary component of a complex type.
          The return value will the same type as the imaginary field
          within the complex type.
*)

PROCEDURE IM (c: <any complex type>) : <floating point type> ;

(*
    INT - returns an INTEGER value which has the same value as v.
          This function is equivalent to: VAL(INTEGER, v).
*)

PROCEDURE INT (v: <any ordinal type>) : INTEGER ;

(*
    LENGTH - returns the length of string a.
*)

PROCEDURE LENGTH (a: ARRAY OF CHAR) : CARDINAL ;

```

This function is evaluated at compile time, providing that string `a` is a constant. If `a` cannot be evaluated then a call is made to `M2RTS.Length`.

```

(*
    ODD - returns a BOOLEAN indicating whether the whole number
          value, v, is odd.

```

```

*)

PROCEDURE ODD (v: <any whole number type>) : BOOLEAN ;

(*
  RE - returns the real component of a complex type.
       The return value will the same type as the real field
       within the complex type.
*)

PROCEDURE RE (c: <any complex type>) : <floating point type> ;

```

## 2.5 Behavior of the high procedure function

This section describes the behavior of the standard procedure function **HIGH** and it includes a table of parameters with the expected return result. The standard procedure function will return the last accessible indice of an **ARRAY**. If the parameter to **HIGH** is a static array then the result will be a **CARDINAL** value matching the upper bound in the **ARRAY** declaration.

The section also describes the behavior of a string literal actual parameter and how it relates to **HIGH**. The PIM2, PIM3, PIM4 and ISO standard is silent on the issue of whether a **nul** is present in an **ARRAY OF CHAR** actual parameter.

If the first parameter to **HIGH** is an unbounded **ARRAY** the return value from **HIGH** will be the last accessible element in the array. If a constant string literal is passed as an actual parameter then it will be **nul** terminated. The table and example code below describe the effect of passing an actual parameter and the expected **HIGH** value.

```

MODULE example1 ;

PROCEDURE test (a: ARRAY OF CHAR) ;
VAR
  x: CARDINAL ;
BEGIN
  x := HIGH (a) ;
  ...
END test ;

BEGIN
  test ('') ;
  test ('1') ;
  test ('12') ;
  test ('123') ;
END example1.

Actual parameter | HIGH (a) | a[HIGH (a)] = nul
=====

```

' '	0	TRUE
'1'	1	TRUE
'12'	2	TRUE
'123'	3	TRUE

A constant string literal will be passed to an `ARRAY OF CHAR` with an appended `nul` `CHAR`. Thus if the constant string literal `' '` is passed as an actual parameter (in example1) then the result from `HIGH(a)` will be 0.

```
MODULE example2 ;

PROCEDURE test (a: ARRAY OF CHAR) ;
VAR
  x: CARDINAL ;
BEGIN
  x := HIGH (a) ;
  ...
END test ;

VAR
  str0: ARRAY [0..0] OF CHAR ;
  str1: ARRAY [0..1] OF CHAR ;
  str2: ARRAY [0..2] OF CHAR ;
  str3: ARRAY [0..3] OF CHAR ;
BEGIN
  str0 := 'a' ;    (* No room for the nul terminator.  *)
  test (str0) ;
  str1 := 'ab' ;   (* No room for the nul terminator.  *)
  test (str1) ;
  str2 := 'ab' ;   (* Terminated with a nul.  *)
  test (str2) ;
  str2 := 'abc' ;  (* Terminated with a nul.  *)
  test (str3) ;
END example2.
```

Actual parameter	HIGH (a)	a[HIGH (a)] = nul
str0	0	FALSE
str1	1	FALSE
atr2	2	TRUE
str3	3	TRUE

## 2.6 GNU Modula-2 supported dialects

This section describes the dialects understood by GNU Modula-2. It also describes the differences between the dialects and any command line switches which determine dialect behaviour.

The GNU Modula-2 compiler is compliant with four dialects of Modula-2. The language as defined in 'Programming in Modula-2' 2nd Edition, Springer Verlag, 1982, 1983

by Niklaus Wirth (PIM2), 'Programming in Modula-2', 3rd Corrected Edition, Springer Verlag, 1985 (PIM3) and 'Programming in Modula-2', 4th Edition, Springer Verlag, 1988 (PIM4) <https://freepages.modula2.org/report4/modula-2.html> and the ISO Modula-2 language as defined in ISO/IEC Information technology - programming languages - part 1: Modula-2 Language, ISO/IEC 10514-1 (1996) (ISO).

The command line switches '-fpim2', '-fpim3', '-fpim4' and '-fiso' can be used to force mutually exclusive features. However by default the compiler will not aggressively fail if a non mutually exclusive feature is used from another dialect. For example it is possible to specify '-fpim2' and still utilize 'DEFINITION' 'MODULES' which have no export list.

Some dialect differences will force a compile time error, for example in PIM2 the user must `IMPORT SIZE` from the module `SYSTEM`, whereas in PIM3 and PIM4 `SIZE` is a pervasive function. Thus compiling PIM4 source code with the '-fpim2' switch will cause a compile time error. This can be fixed quickly with an additional `IMPORT` or alternatively by compiling with the '-fpim4' switch.

However there are some very important differences between the dialects which are mutually exclusive and therefore it is vital that users choose the dialects with care when these language features are used.

### 2.6.1 Integer division, remainder and modulus

The most dangerous set of mutually exclusive features found in the four dialects supported by GNU Modula-2 are the `INTEGER` division, remainder and modulus arithmetic operators. It is important to note that the same source code can be compiled to give different run time results depending upon these switches! The reference manual for the various dialects of Modula-2 are quite clear about this behavior and sadly there are three distinct definitions.

The table below illustrates the problem when a negative operand is used.

		Pim2/3		Pim4		ISO			
		-----		-----		-----			
lval	rval	DIV	MOD	DIV	MOD	DIV	MOD	/	REM
31	10	3	1	3	1	3	1	3	1
-31	10	-3	-1	-4	9	-4	9	-3	-1
31	-10	-3	1	-3	1	Exception		-3	1
-31	-10	3	-1	4	9	Exception		3	-1

See also P24 of PIM2, P27 of PIM3, P29 of PIM4 and P201 of the ISO Standard. At present all dialect division, remainder and modulus are implemented as above, apart from the exception calling in the ISO dialect. Instead of exception handling the results are the same as the PIM4 dialect. This is a temporary implementation situation.

## 2.7 Module Search Path

This section describes the default module search path and how this might be changed. By default the compiler will search the current directory, local include dir, prefix include dir, gcc version specific modules and lastly native system header dir. The exact location and whether all these directories are used depends upon the configuration options used when building GCC.

The '-I' option option can be used to introduce new directories in the module search path and for convenience the options '-flibs=' and '-fm2-pathname-root=' are also provided.

The site wide modules are typically located at *prefix/include/m2* whereas the version specific modules are located in *libsubdir/m2*. Both of these */m2* directories are organized such that the non dialect specific modules are at the top and dialect specific modules are in subdirectories.

The ‘-fm2-pathname-root=’ option is equivalent to adding a ‘-I’ path for every library dialect. For example if the library dialect order is selected by ‘-flibs=pim,iso,log’ and ‘-fm2-pathname-root=foo’ is supplied then this is equivalent to the following pairs of options:

```
-fm2-pathname=m2pim -Ifoo/m2/m2pim
-fm2-pathname=m2iso -Ifoo/m2/m2iso
-fm2-pathname=m2log -Ifoo/m2/m2log
-fm2-pathname=- -Ifoo/m2
```

The option ‘-fsources’ will show the source module, path and pathname for each module parsed.

## 2.8 Exception implementation

This section describes how exceptions are implemented in GNU Modula-2 and how command line switches affect their behavior. The option ‘-fsoft-check-all’ enables all software checking of nil dereferences, division by zero etc. Additional code is produced to check these conditions and exception handlers are invoked if the conditions prevail.

Without ‘-fsoft-check-all’ these exceptions will be caught by hardware (assuming the hardware support exists) and a signal handler is invoked. The signal handler will in turn THROW an exception which will be caught by the appropriate Modula-2 handler. However the action of throwing an exception from within a signal handler is implementation defined (according to the C++ documentation). For example on the x86\_64 architecture this works whereas on the i686 architecture it does not. Therefore to ensure portability it is recommended to use ‘-fsoft-check-all’.

2

## 2.9 How to detect run time problems at compile time

Consider the following program:

```
MODULE assignvalue ; (*!m2iso+gm2*)

PROCEDURE bad () : INTEGER ;
VAR
  i: INTEGER ;
BEGIN
  i := -1 ;
  RETURN i
END bad ;

VAR
```

---

<sup>2</sup> ‘-fsoft-check-all’ can be effectively combined with ‘-O2’ to semantically analyze source code for possible run time errors at compile time.

```

    foo: CARDINAL ;
BEGIN
    (* The m2rte plugin will detect this as an error, post
       optimization.  *)
    foo := bad ()
END assignvalue.

```

here we see that the programmer has overlooked that the return value from ‘bad’ will cause an overflow to ‘foo’. If we compile the code with the following options:

```

$ gm2 -g -fsoft-check-all -O2 -fm2-plugin -c assignvalue.mod
assignvalue.mod:16:0:inevitable that this error will occur at run time,
assignment will result in an overflow

```

The gm2 semantic plugin is automatically run and will generate a warning message for every exception call which is known as reachable. It is highly advised to run the optimizer (‘-O2’ or ‘-O3’) with ‘-fsoft-check-all’ so that the compiler is able to run the optimizer and perform variable and flow analysis before the semantic plugin is invoked.

The ‘-Wuninit-variable-checking’ can be used to identify uninitialized variables within the first basic block in a procedure. The checking is limited to variables so long as they are not an array or set or a variant record or var parameter.

The following example detects whether a sub component within a record is uninitialized.

```

MODULE testlarge2 ;

TYPE
    color = RECORD
        r, g, b: CARDINAL ;
    END ;

    pixel = RECORD
        fg, bg: color ;
    END ;

PROCEDURE test ;
VAR
    p: pixel ;
BEGIN
    p.fg.r := 1 ;
    p.fg.g := 2 ;
    p.fg.g := 3 ;    (* Deliberate typo should be p.fg.b.  *)
    p.bg := p.fg ;   (* Accessing an uninitialized field.  *)
END test ;

BEGIN
    test
END testlarge2.

```

```

$ gm2 -c -Wuninit-variable-checking testlarge2.mod
testlarge2.mod:19:13: warning: In procedure ‘test’: attempting to

```

```

access expression before it has been initialized
19 |   p.bg := p.fg ;   (* Accessing an uninitialized field.  *)
   |   ~~~~

```

The following example detects if an individual field is uninitialized.

```

MODULE testwithnoptr ;

TYPE
  Vec = RECORD
    x, y: CARDINAL ;
  END ;

PROCEDURE test ;
VAR
  p: Vec ;
BEGIN
  WITH p DO
    x := 1 ;
    x := 2   (* Deliberate typo, user meant y.  *)
  END ;
  IF p.y = 2
  THEN
  END
END test ;

BEGIN
  test
END testwithnoptr.

```

The following example detects a record is uninitialized via a pointer variable in a ‘WITH’ block.

```

$ gm2 -g -c -Wuninit-variable-checking testwithnoptr.mod
testwithnoptr.mod:21:8: warning: In procedure ‘test’: attempting to
access expression before it has been initialized
21 |   IF p.y = 2
   |   ~~~~

```

```

MODULE testnew6 ;

FROM Storage IMPORT ALLOCATE ;

TYPE
  PtrToVec = POINTER TO RECORD
    x, y: INTEGER ;
  END ;

PROCEDURE test ;
VAR
  p: PtrToVec ;

```

```

BEGIN
  NEW (p) ;
  WITH p^ DO
    x := 1 ;
    x := 2  (* Deliberate typo, user meant y.  *)
  END ;
  IF p^.y = 2
  THEN
  END
END test ;

BEGIN
  test
END testnew6.

$ gm2 -g -c -Wuninit-variable-checking testnew6.mod
testnew6.mod:19:9: warning: In procedure 'test': attempting to
access expression before it has been initialized
19 |      IF p^.y = 2
    |          ~~~~

```

## 2.10 GNU Modula-2 language extensions

This section introduces the GNU Modula-2 language extensions. The GNU Modula-2 compiler allows abstract data types to be any type, not just restricted to a pointer type providing the ‘-fextended-opaque’ option is supplied See Section 2.2 [Compiler options], page 3.

Declarations can be made in any order, whether they are types, constants, procedures, nested modules or variables.

GNU Modula-2 also allows programmers to interface to C and assembly language.

GNU Modula-2 provides support for the special tokens `__LINE__`, `__FILE__`, `__FUNCTION__` and `__DATE__`. Support for these tokens will occur even if the ‘-fcpp’ option is not supplied. A table of these identifiers and their data type and values is given below:

Scope	GNU Modula-2 token	Data type and example value
anywhere	<code>__LINE__</code>	Constant Literal compatible with <code>CARDINAL</code> , <code>INTEGER</code> and <code>WORD</code> . Example 1234
anywhere	<code>__FILE__</code>	Constant string compatible with parameter <code>ARRAY OF CHAR</code> or an <code>ARRAY</code> whose <code>SIZE</code> is $\geq$ string length. Example "hello.mod"
procedure	<code>__FUNCTION__</code>	Constant string compatible

		with parameter ARRAY OF CHAR or an ARRAY whose SIZE is $\geq$ string length. Example "calc"
module	__FUNCTION__	Example "module hello initialization"
anywhere	__DATE__	Constant string compatible with parameter ARRAY OF CHAR or an ARRAY whose SIZE is $\geq$ string length. Example "Thu Apr 29 10:07:16 BST 2004"
anywhere	__COLUMN__	Gives a constant literal number determining the left hand column where the first _ appears in __COLUMN__. The left most column is 1.

The preprocessor 'cpp' can be invoked via the '-fcpp' command line option. This in turn invokes 'cpp' with the following arguments '-traditional -lang-asm'. These options preserve comments and all quotations. 'gm2' treats a '#' character in the first column as a preprocessor directive unless '-fno-cpp' is supplied.

For example here is a module which calls FatalError via the macro ERROR.

```

MODULE cpp ;

FROM SYSTEM IMPORT ADR, SIZE ;
FROM libc IMPORT exit, printf, malloc ;

PROCEDURE FatalError (a, file: ARRAY OF CHAR;
                      line: CARDINAL;
                      func: ARRAY OF CHAR) ;
BEGIN
  printf ("%s:%d:fatal error, %s, in %s\n",
          ADR (file), line, ADR (a), ADR (func)) ;
  exit (1)
END FatalError ;

#define ERROR(X) FatalError(X, __FILE__, __LINE__, __FUNCTION__)

VAR
  pc: POINTER TO CARDINAL;
BEGIN
  pc := malloc (SIZE (CARDINAL)) ;
  IF pc = NIL

```

```

    THEN
        ERROR ('out of memory')
    END
END cpp.

```

Another use for the C preprocessor in Modula-2 might be to turn on debugging code. For example the library module `FormatStrings.mod` uses procedures from `DynamicStrings.mod` and to track down memory leaks it was useful to track the source file and line where each string was created. Here is a section of `FormatStrings.mod` which shows how the debugging code was enabled and disabled by adding `-fcpp` to the command line.

```

FROM DynamicStrings IMPORT String, InitString, InitStringChar, Mark,
                               Concat, Slice, Index, char,
                               Assign, Length, Mult, Dup, ConcatChar,
                               PushAllocation, PopAllocationExemption,
                               InitStringDB, InitStringCharStarDB,
                               InitStringCharDB, MultDB, DupDB, SliceDB ;

(*
#define InitString(X) InitStringDB(X, __FILE__, __LINE__)
#define InitStringCharStar(X) InitStringCharStarDB(X, __FILE__, \
                                                    __LINE__)
#define InitStringChar(X) InitStringCharDB(X, __FILE__, __LINE__)
#define Mult(X,Y) MultDB(X, Y, __FILE__, __LINE__)
#define Dup(X) DupDB(X, __FILE__, __LINE__)
#define Slice(X,Y,Z) SliceDB(X, Y, Z, __FILE__, __LINE__)
*)

PROCEDURE doDSdbEnter ;
BEGIN
    PushAllocation
END doDSdbEnter ;

PROCEDURE doDSdbExit (s: String) ;
BEGIN
    s := PopAllocationExemption (TRUE, s)
END doDSdbExit ;

PROCEDURE DSdbEnter ;
BEGIN
END DSdbEnter ;

PROCEDURE DSdbExit (s: String) ;
BEGIN
END DSdbExit ;

(*

```

```

#define DBsbEnter doDBsbEnter
#define DBsbExit  doDBsbExit
*)

PROCEDURE Sprintf1 (s: String; w: ARRAY OF BYTE) : String ;
BEGIN
    DSdbEnter ;
    s := FormatString (HandleEscape (s), w) ;
    DSdbExit (s) ;
    RETURN s
END Sprintf1 ;

```

It is worth noting that the overhead of this code once `-fcpp` is not present and `-O2` is used will be zero since the local empty procedures `DSdbEnter` and `DSdbExit` will be thrown away by the optimization passes of the GCC backend.

### 2.10.1 Optional procedure parameter

GNU Modula-2 allows the last parameter to a procedure or function parameter to be optional. For example in the ISO library `COROUTINES.def` the procedure `NEWCOROUTINE` is defined as having an optional fifth argument (`initProtection`) which, if absent, is automatically replaced by `NIL`.

```

PROCEDURE NEWCOROUTINE (procBody: PROC; workspace: SYSTEM.ADDRESS;
                        size: CARDINAL; VAR cr: COROUTINE;
                        [initProtection: PROTECTION = NIL]);

```

```

(* Creates a new coroutine whose body is given by procBody,
   and returns the identity of the coroutine in cr.
   workspace is a pointer to the work space allocated to
   the coroutine; size specifies the size of this workspace
   in terms of SYSTEM.LOC.

```

```

   The optional fifth argument may contain a single parameter
   which specifies the initial protection level of the coroutine.

```

```

*)

```

The implementation module `COROUTINES.mod` implements this procedure using the following syntax:

```

PROCEDURE NEWCOROUTINE (procBody: PROC; workspace: SYSTEM.ADDRESS;
                        size: CARDINAL; VAR cr: COROUTINE;
                        [initProtection: PROTECTION]);

BEGIN

END NEWCOROUTINE ;

```

Note that it is illegal for this declaration to contain an initializer value for `initProtection`. However it is necessary to surround this parameter with the brackets `[` and `]`. This serves to remind the programmer that the last parameter was declared as optional in the definition module.

Local procedures can be declared to have an optional final parameter in which case the initializer is mandatory in the implementation or program module.

GNU Modula-2 also provides additional fixed sized data types which are all exported from the `SYSTEM` module. See Section 2.22 [The PIM system module], page 52. See Section 2.23 [The ISO system module], page 56.

## 2.11 Type compatibility

This section discuss the issues surrounding assignment, expression and parameter compatibility, their effect of the additional fixed sized datatypes and also their effect of run time checking. The data types supported by the compiler are:

GNU Modula-2	scope	switches
=====		
INTEGER	pervasive	
LONGINT	pervasive	
SHORTINT	pervasive	
CARDINAL	pervasive	
LONGCARD	pervasive	
SHORTCARD	pervasive	
BOOLEAN	pervasive	
BITSET	pervasive	
REAL	pervasive	
LONGREAL	pervasive	
SHORTREAL	pervasive	
CHAR	pervasive	
SHORTCOMPLEX	pervasive	
COMPLEX	pervasive	
LONGCOMPLEX	pervasive	
LOC	SYSTEM	-fiso
BYTE	SYSTEM	
WORD	SYSTEM	
ADDRESS	SYSTEM	

The following extensions are supported for most architectures (please check `SYSTEM.def`).

=====	
INTEGER8	SYSTEM
INTEGER16	SYSTEM
INTEGER32	SYSTEM
INTEGER64	SYSTEM
CARDINAL8	SYSTEM
CARDINAL16	SYSTEM
CARDINAL32	SYSTEM
CARDINAL64	SYSTEM
BITSET8	SYSTEM
BITSET16	SYSTEM

BITSET32	SYSTEM
WORD16	SYSTEM
WORD32	SYSTEM
WORD64	SYSTEM
REAL32	SYSTEM
REAL64	SYSTEM
REAL96	SYSTEM
REAL128	SYSTEM
COMPLEX32	SYSTEM
COMPLEX64	SYSTEM
COMPLEX96	SYSTEM
COMPLEX128	SYSTEM

The Modula-2 language categorizes compatibility between entities of possibly differing types into three sub components: expressions, assignments, and parameters. Parameter compatibility is further divided into two sections for pass by reference and pass by value compatibility.

For more detail on the Modula-2 type compatibility see the Modula-2 ISO standard BS ISO/IEC 10514-1:1996 page 121-125. For detail on the PIM type compatibility see Programming in Modula-2 Edition 4 page 29, (Elementary Data Types).

### 2.11.1 Expression compatibility

Modula-2 restricts the types of expressions to the same type. Expression compatibility is a symmetric relation.

For example two sub expressions of `INTEGER` and `CARDINAL` are not expression compatible (<https://freepages.modula2.org/report4/modula-2.html> and ISO Modula-2).

In GNU Modula-2 this rule is also extended across all fixed sized data types (imported from `SYSTEM`).

### 2.11.2 Assignment compatibility

This section discusses the assignment issues surrounding assignment compatibility of elementary types (`INTEGER`, `CARDINAL`, `REAL` and `CHAR` for example). The information here is found in more detail in the Modula-2 ISO standard BS ISO/IEC 10514-1:1996 page 122.

Assignment compatibility exists between the same sized elementary types.

Same type family of different sizes are also compatible as long as the `MAX(type)` and `MIN(type)` is known. So for example this includes the `INTEGER` family, `CARDINAL` family and the `REAL` family.

The reason for this is that when the assignment is performed the compiler will check to see that the expression (on the right of the `:=`) lies within the range of the designator type (on the left hand side of the `:=`). Thus these ordinal types can be assignment compatible. However it does mean that `WORD32` is not compatible with `WORD16` as `WORD32` does not have a minimum or maximum value and therefore cannot be checked. The compiler does not know which of the two bytes from `WORD32` should be copied into `WORD16` and which two should be ignored. Currently the types `BITSET8`, `BITSET16` and `BITSET32` are assignment incompatible. However this restriction maybe lifted when further run time checking is achieved.

Modula-2 does allow `INTEGER` to be assignment compatible with `WORD` as they are the same size. Likewise GNU Modula-2 allows `INTEGER16` to be compatible with `WORD16` and the same for the other fixed sized types and their sized equivalent in either `WORDn`, `BYTE` or `LOC` types. However it prohibits assignment between `WORD` and `WORD32` even though on many systems these sizes will be the same. The reasoning behind this rule is that the extended fixed sized types are meant to be used by applications requiring fixed sized data types and it is more portable to forbid the blurring of the boundaries between fixed sized and machine dependent sized types.

Intermediate code run time checking is always generated by the front end. However this intermediate code is only translated into actual code if the appropriate command line switches are specified. This allows the compiler to perform limited range checking at compile time. In the future it will allow the extensive GCC optimizations to propagate constant values through to the range checks which if they are found to exceed the type range will result in a compile time error message.

### 2.11.3 Parameter compatibility

Parameter compatibility is divided into two areas, pass by value and pass by reference (`VAR`). In the case of pass by value the rules are exactly the same as assignment. However in the second case, pass by reference, the actual parameter and formal parameter must be the same size and family. Furthermore `INTEGER` and `CARDINALs` are not treated as compatible in the pass by reference case.

The types `BYTE`, `LOC`, `WORD` and `WORDn` derivatives are assignment and parameter compatible with any data type of the same size.

## 2.12 Exception handling

This section gives an example of exception handling and briefly describes its runtime behavior. The module below is written in the ISO dialect of Modula-2 and can be compiled with the command line:

```
$ gm2 -g -fiso -fsoft-check-all lazyunique.mod
```

The option `'-fsoft-check-all'` generates checks for `NIL` pointer access violation. In turn this will call the exception handler.

```

MODULE lazyunique ;  (*!m2iso+gm2*)

FROM Storage IMPORT ALLOCATE ;
FROM libc IMPORT printf, exit ;

TYPE
  List = POINTER TO RECORD
    next : List ;
    value: INTEGER ;
  END ;

  Array = ARRAY [0..3] OF INTEGER ;

CONST
  Unsorted = Array {0, 2, 1, 1} ;

VAR
  head: List ;

PROCEDURE Display ;
VAR
  p: List ;
BEGIN
  p := head^.next ;
  printf ("\nunique data\n");
  printf ("=====\n");
  WHILE p # NIL DO
    printf ("%d\n", p^.value);
    p := p^.next
  END
END Display ;

PROCEDURE Add (VAR p: List; val: INTEGER) ;
BEGIN
  NEW (p) ;
  WITH p^ DO
    value := val ;
    next := NIL
  END
END Add ;

```

```

PROCEDURE Unique (val: INTEGER) ;
VAR
    p: List ;
BEGIN
    printf ("new value %d\n", val);
    p := head ;
    (* The following line may cause an exception accessing next or
       value. *)
    WHILE p^.next^.value # val DO
        p := p^.next
    END
EXCEPT
    (* Now fixup. Determine the source of the exception and retry. *)
    IF head = NIL
    THEN
        printf ("list was empty, add sentinal\n");
        Add (head, -1) ;
        RETRY (* Jump back to the begin statement. *)
    ELSIF p^.next = NIL
    THEN
        printf ("growing the list\n");
        Add (p^.next, val) ;
        RETRY (* Jump back to the begin statement. *)
    ELSE
        printf ("should never reach here!\n");
    END
END Unique ;

```

```

PROCEDURE unique ;
VAR
    i: CARDINAL ;
BEGIN
    FOR i := 0 TO HIGH (Unsorted) DO
        Unique (Unsorted[i])
    END ;
    Display
END unique ;

BEGIN
    head := NIL ;
    unique
END lazyunique.

```

```

new value 0
list was empty, add sentinel
new value 0
growing the list
new value 0
new value 2
growing the list
new value 2
new value 1
growing the list
new value 1
new value 1

unique data
=====
0
2
1

```

## 2.13 Unbounded by reference

This section documents a GNU Modula-2 compiler switch which implements a language optimization surrounding the implementation of unbounded arrays. In GNU Modula-2 the unbounded array is implemented by utilizing an internal structure `struct {dataType *address, unsigned int high}`. So given the Modula-2 procedure declaration:

```

PROCEDURE foo (VAR a: ARRAY OF dataType) ;
BEGIN
    IF a[2]= (* etc *)
END foo ;

```

it is translated into GCC trees, which can be represented in their C form thus:

```

void foo (struct {dataType *address, unsigned int high} a)
{
    if (a.address[2] == /* etc */)
}

```

Whereas if the procedure foo was declared as:

```

PROCEDURE foo (a: ARRAY OF dataType) ;
BEGIN
    IF a[2]= (* etc *)
END foo ;

```

then it is implemented by being translated into the following GCC trees, which can be represented in their C form thus:

```

void foo (struct {dataType *address, unsigned int high} a)
{
    dataType *copyContents = (dataType *)alloca (a.high+1);
    memcpy(copyContents, a.address, a.high+1);
    a.address = copyContents;
}

```

```

    if (a.address[2] == /* etc */)
}

```

This implementation works, but it makes a copy of each non VAR unbounded array when a procedure is entered. If the unbounded array is not changed during procedure `foo` then this implementation will be very inefficient. In effect Modula-2 lacks the `REF` keyword of Ada. Consequently the programmer maybe tempted to sacrifice semantic clarity for greater efficiency by declaring the parameter using the `VAR` keyword in place of `REF`.

The `-funbounded-by-reference` switch instructs the compiler to check and see if the programmer is modifying the content of any unbounded array. If it is modified then a copy will be made upon entry into the procedure. Conversely if the content is only read and never modified then this non VAR unbounded array is a candidate for being passed by reference. It is only a candidate as it is still possible that passing this parameter by reference could alter the meaning of the source code. For example consider the following case:

```

PROCEDURE StrConCat (VAR a: ARRAY OF CHAR; b, c: ARRAY OF CHAR) ;
BEGIN
    (* code which performs string a := b + c *)
END StrConCat ;

PROCEDURE foo ;
VAR
    a: ARRAY [0..3] OF CHAR ;
BEGIN
    a := 'q' ;
    StrConCat(a, a, a)
END foo ;

```

In the code above we see that the same parameter, `a`, is being passed three times to `StrConCat`. Clearly even though parameters `b` and `c` are never modified it would be incorrect to implement them as pass by reference. Therefore the compiler checks to see if any non VAR parameter is type compatible with any VAR parameter and if so it generates run time procedure entry checks to determine whether the contents of parameters `b` or `c` matches the contents of `a`. If a match is detected then a copy is made and the `address` in the unbounded structure is modified.

The compiler will check the address range of each candidate against the address range of any VAR parameter, providing they are type compatible. For example consider:

```

PROCEDURE foo (a: ARRAY OF BYTE; VAR f: REAL) ;
BEGIN
    f := 3.14 ;
    IF a[0]=BYTE(0)
    THEN
        (* etc *)
    END
END foo ;

PROCEDURE bar ;

```

```

BEGIN
    r := 2.0 ;
    foo(r, r)
END bar ;

```

Here we see that although parameter, `a`, is a candidate for the passing by reference, it would be incorrect to use this transformation. Thus the compiler detects that parameters, `a` and `f` are type compatible and will produce run time checking code to test whether the address range of their respective contents intersect.

## 2.14 Building a shared library

This section describes building a tiny shared library implemented in Modula-2 and built with `libtool`. Suppose a project consists of two definition modules and two implementation modules and a program module `a.def`, `a.mod`, `b.def`, `b.mod` and `c.mod`. The first step is to compile the modules using position independent code. This can be achieved by the following three commands:

```

libtool --tag=CC --mode=compile gm2 -g -c a.mod -o a.lo
libtool --tag=CC --mode=compile gm2 -g -c b.mod -o b.lo
libtool --tag=CC --mode=compile gm2 -g -c c.mod -o c.lo

```

The second step is to generate the shared library initialization and finalization routines. We can do this by asking `gm2` to generate a list of dependent modules and then use this to generate the scaffold. We also must compile the scaffold.

```

gm2 -c -g -fmakelist c.mod
gm2 -c -g -fmakeinit -fshared c.mod
libtool --tag=CC --mode=compile g++ -g -c c_m2.cpp -o c_m2.lo

```

The third step is to link all these `.lo` files.

```

libtool --mode=link gcc -g c_m2.lo a.lo b.lo c.lo \
    -L$(prefix)/lib64 \
    -rpath `pwd` -lgm2 -lstdc++ -lm -o libabc.la

```

At this point the shared library `libabc.so` will have been created inside the directory `.libs`.

## 2.15 How to produce swig interface files

This section describes how Modula-2 implementation modules can be called from Python (and other scripting languages such as TCL and Perl). GNU Modula-2 can be instructed to create a swig interface when it is compiling an implementation module. Swig then uses the interface file to generate all the necessary wrapping so that the desired scripting language may access the implementation module.

Here is an example of how you might call upon the services of the Modula-2 library module `NumberIO` from Python3.

The following commands can be used to generate the Python3 module:

```

export src='directory to the sources'
export prefix='directory where the compiler is installed'
gm2 -I${src} -c -g -fswig ${src}/../../gm2-libs/NumberIO.mod

```

```

gm2 -I${src} -c -g -fmakelist ${src}/../.../gm2-libs/NumberIO.mod

gm2 -I${src} -c -g -fmakeinit -fshared \
    ${src}/../.../gm2-libs/NumberIO.mod

swig -c++ -python3 NumberIO.i

libtool --mode=compile g++ -g -c -I${src} NumberIO_m2.cpp \
    -o NumberIO_m2.lo

libtool --tag=CC --mode=compile gm2 -g -c \
    -I${src}/../.../gm2-libs \
    ${src}/../.../gm2-libs/NumberIO.mod -o NumberIO.lo

libtool --tag=CC --mode=compile g++ -g -c NumberIO_wrap.cxx \
    -I/usr/include/python3 -o NumberIO_wrap.lo

libtool --mode=link gcc -g NumberIO_m2.lo NumberIO_wrap.lo \
    -L${prefix}/lib64 \
    -rpath `pwd` -lgm2 -lstdc++ -lm -o libNumberIO.la

cp .libs/libNumberIO.so _NumberIO.so

```

The first four commands, generate the swig interface file `NumberIO.i` and python wrap files `NumberIO_wrap.cxx` and `NumberIO.py`. The next three `libtool` commands compile the C++ and Modula-2 source code into `.lo` objects. The last `libtool` command links all the `.lo` files into a `.la` file and includes all shared library dependencies.

Now it is possible to run the following Python script (called `testnum.py`):

```

import NumberIO

print ("1234 x 2 =", NumberIO.NumberIO_StrToInt("1234")*2)

```

like this:

```

$ python3 testnum.py
1234 x 2 = 2468

```

See Section 2.16 [Producing a Python module], page 36, for another example which uses the `UNQUALIFIED` keyword to reduce the module name clutter from the viewpoint of Python3.

### 2.15.1 Limitations of automatic generated of Swig files

This section discusses the limitations of automatically generating swig files. From the previous example we see that the module `NumberIO` had a swig interface file `NumberIO.i` automatically generated by the compiler. If we consider three of the procedure definitions in `NumberIO.def` we can see the success and limitations of the automatic interface generation.

```

PROCEDURE StrToHex (a: ARRAY OF CHAR; VAR x: CARDINAL) ;
PROCEDURE StrToInt (a: ARRAY OF CHAR; VAR x: INTEGER) ;
PROCEDURE ReadInt (VAR x: CARDINAL) ;

```

Below are the swig interface prototypes:

```

extern void NumberIO_StrToHex (char *_m2_address_a,
                               int _m2_high_a, unsigned int *OUTPUT);
/* parameters: x is known to be an OUTPUT */
extern void NumberIO_StrToInt (char *_m2_address_a,
                               int _m2_high_a, int *OUTPUT);
/* parameters: x is guessed to be an OUTPUT */
extern void NumberIO_ReadInt (int *x);
/* parameters: x is unknown */

```

In the case of `StrToHex` it can be seen that the compiler detects that the last parameter is an output. It explicitly tells swig this by using the parameter name `OUTPUT` and in the following comment it informs the user that it knows this to be an output parameter. In the second procedure `StrToInt` it marks the final parameter as an output, but it tells the user that this is only a guess. Finally in `ReadInt` it informs the user that it does not know whether the parameter, `x`, is an output, input or an inout parameter.

The compiler decides whether to mark a parameter as either: `INPUT`, `OUTPUT` or `INOUT` if it is read before written or visa versa in the first basic block. At this point it will write output that the parameter is known. If it is not read or written in the first basic block then subsequent basic blocks are searched and the result is commented as a guess. Finally if no read or write occurs then the parameter is commented as unknown. However, clearly it is possible to fool this mechanism. Nevertheless automatic generation of implementation module into swig interface files was thought sufficiently useful despite these limitations.

In conclusion it would be wise to check all parameters in any automatically generated swig interface file. Furthermore you can force the automatic mechanism to generate correct interface files by reading or writing to the `VAR` parameter in the first basic block of a procedure.

## 2.16 How to produce a Python module

This section describes how it is possible to produce a Python module from Modula-2 code. There are a number of advantages to this approach, it ensures your code reaches a wider audience, maybe it is easier to initialize your application in Python.

The example application here is a pedagogical two dimensional gravity next event simulation. The Python module needs to have a clear API which should be placed in a single definition module. Furthermore the API should only use fundamental pervasive data types and strings. Below the API is contained in the file `twoDsim.def`:

```

DEFINITION MODULE twoDsim ;

EXPORT UNQUALIFIED gravity, box, poly3, poly5, poly6, mass,
                    fix, circle, pivot, velocity, accel, fps,
                    replayRate, simulateFor ;

(*
  gravity - turn on gravity at: g m^2
*)

PROCEDURE gravity (g: REAL) ;

```

```

(*
  box - place a box in the world at (x0,y0),(x0+i,y0+j)
*)

PROCEDURE box (x0, y0, i, j: REAL) : CARDINAL ;

(*
  poly3 - place a triangle in the world at:
          (x0,y0),(x1,y1),(x2,y2)
*)

PROCEDURE poly3 (x0, y0, x1, y1, x2, y2: REAL) : CARDINAL ;

(*
  poly5 - place a pentagon in the world at:
          (x0,y0),(x1,y1),(x2,y2),(x3,y3),(x4,y4)
*)

PROCEDURE poly5 (x0, y0, x1, y1,
                 x2, y2, x3, y3, x4, y4: REAL) : CARDINAL ;

(*
  poly6 - place a hexagon in the world at:
          (x0,y0),(x1,y1),(x2,y2),(x3,y3),(x4,y4),(x5,y5)
*)

PROCEDURE poly6 (x0, y0, x1, y1,
                 x2, y2, x3, y3,
                 x4, y4, x5, y5: REAL) : CARDINAL ;

(*
  mass - specify the mass of an object and return the, id.
*)

PROCEDURE mass (id: CARDINAL; m: REAL) : CARDINAL ;

(*
  fix - fix the object to the world.
*)

PROCEDURE fix (id: CARDINAL) : CARDINAL ;

```

```
(*
  circle - adds a circle to the world.  Center
          defined by: x0, y0 radius, r.
*)

PROCEDURE circle (x0, y0, r: REAL) : CARDINAL ;

(*
  velocity - give an object, id, a velocity, vx, vy.
*)

PROCEDURE velocity (id: CARDINAL; vx, vy: REAL) : CARDINAL ;

(*
  accel - give an object, id, an acceleration, ax, ay.
*)

PROCEDURE accel (id: CARDINAL; ax, ay: REAL) : CARDINAL ;

(*
  fps - set frames per second.
*)

PROCEDURE fps (f: REAL) ;

(*
  replayRate - set frames per second during replay.
*)

PROCEDURE replayRate (f: REAL) ;

(*
  simulateFor - render for, t, seconds.
*)

PROCEDURE simulateFor (t: REAL) ;

END twoDsim.
```

The keyword `UNQUALIFIED` can be used to ensure that the compiler will provide externally accessible functions `gravity`, `box`, `poly3`, `poly5`, `poly6`, `mass`, `fix`, `circle`, `pivot`, `velocity`, `accel`, `fps`, `replayRate`, `simulateFor` rather than name mangled alternatives. Hence in our Python3 application we could write:

```
#!/usr/bin/env python3

from twoDsim import *

b = box (0.0, 0.0, 1.0, 1.0)
b = fix (b)
c1 = circle (0.7, 0.7, 0.05)
c1 = mass (c1, 0.01)
c2 = circle (0.7, 0.1, 0.05)
c2 = mass (c2, 0.01)
c2 = fix (c2)
gravity (-9.81)
fps (24.0*4.0)
replayRate (24.0)
print ("creating frames")
try:
    simulateFor (1.0)
    print ("all done")
except:
    print ("exception raised")
```

which accesses the various functions defined and implemented by the module `twoDsim`. The Modula-2 source code is compiled via:

```
$ gm2 -g -fiso -c -fswig twoDsim.mod
$ gm2 -g -fiso -c -fmakelist twoDsim.mod
$ gm2 -g -fiso -c -fmakeinit twoDsim.mod
```

The first command both compiles the source file creating `twoDsim.o` and produces a swig interface file `swig.i`. We now use `swig` and `g++` to produce and compile the interface wrappers:

```
$ libtool --mode=compile g++ -g -c twoDsim_m2.cpp -o twoDsim_m2.lo
$ swig -c++ -python3 twoDsim.i
$ libtool --mode=compile g++ -c -fPIC twoDsim_wrap.cxx \
  -I/usr/include/python3 -o twoDsim_wrap.lo
$ libtool --mode=compile gm2 -g -fPIC -fiso -c deviceGnuPic.mod
$ libtool --mode=compile gm2 -g -fPIC -fiso -c roots.mod
$ libtool --mode=compile gm2 -g -fPIC -fiso -c -fswig \
  twoDsim.mod -o twoDsim.lo
```

Finally the application is linked into a shared library:

```
$ libtool --mode=link gcc -g twoDsim_m2.lo twoDsim_wrap.lo \
  roots.lo deviceGnuPic.lo \
  -L${prefix}/lib64 \
  -rpath `pwd` -lgm2 -lstlstdc++ -lm -o libtwoDsim.la
```

```
cp .libs/libtwoDsim.so _twoDsim.so
```

The library name must start with `_` to comply with the Python3 module naming scheme.

## 2.17 Interfacing GNU Modula-2 to C

The GNU Modula-2 compiler tries to use the C calling convention wherever possible however some parameters have no C equivalent and thus a language specific method is used. For example unbounded arrays are passed as a `struct {void *address, unsigned int high}` and the contents of these arrays are copied by callee functions when they are declared as non `VAR` parameters. The `VAR` equivalent unbounded array parameters need no copy, but still use the `struct` representation.

The recommended method of interfacing GNU Modula-2 to C is by telling the definition module that the implementation is in the C language. This is achieved by using the tokens `DEFINITION MODULE FOR "C"`. Here is an example `libprintf.def`.

```
DEFINITION MODULE FOR "C" libprintf ;

EXPORT UNQUALIFIED printf ;

PROCEDURE printf (a: ARRAY OF CHAR; ...) : [ INTEGER ] ;

END libprintf.
```

the `UNQUALIFIED` keyword in the definition module informs GNU Modula-2 not to prefix the module name to exported references in the object file.

The `printf` declaration states that the first parameter semantically matches `ARRAY OF CHAR` but since the module is for the C language it will be mapped onto `char *`. The token `...` indicates a variable number of arguments (varargs) and all parameters passed here are mapped onto their C equivalents. Arrays and constant strings are passed as pointers. Lastly `[ INTEGER ]` states that the caller can ignore the function return result if desired.

The hello world program can be rewritten as:

```
MODULE hello ;

FROM libprintf IMPORT printf ;

BEGIN
  printf ("hello world\n")
END hello.
```

and it can be compiled by:

```
'gm2 -g hello.mod -lc'
```

In reality the `'-lc'` is redundant as `libc` is always included in the linking process. It is shown here to emphasize that the C library or object file containing `printf` must be present. The search path for modules can be changed by using `'-I'`.

If a procedure function is declared using varargs then some parameter values are converted. The table below summarizes the default conversions and default types used.

Actual Parameter		Default conversion		Type of actual
------------------	--	--------------------	--	----------------

			value passed
=====			=====
123		none	long long int
"hello world"		none	const char *
a: ARRAY OF CHAR		ADR (a)	char *
a: ARRAY [0..5] OF CHAR		ADR (a)	char *
3.14		none	long double

If you wish to pass `int` values then you should explicitly convert the constants using one of the conversion mechanisms. For example: `INTEGER(10)` or `VAL(INTEGER, 10)` or `CAST(INTEGER, 10)`.

## 2.18 Interface to assembly language

The interface for GNU Modula-2 to assembly language is almost identical to GNU C. The only alterations are that the keywords `asm` and `volatile` are in capitals, following the Modula-2 convention.

A simple, but highly non optimal, example is given below. Here we want to add the two `CARDINAL`s `foo` and `bar` together and return the result. The target processor is assumed to be executing the x86\_64 instruction set.

```

PROCEDURE Example (foo, bar: CARDINAL) : CARDINAL ;
VAR
  myout: CARDINAL ;
BEGIN
  ASM VOLATILE ("movl %1,%%eax; addl %2,%%eax; movl %%eax,%0"
    : "=rm" (myout)           (* outputs *)
    : "rm" (foo), "rm" (bar)  (* inputs *)
    : "eax");                 (* we trash *)
  RETURN( myout )
END Example ;

```

For a full description of this interface we refer the reader to the GNU C manual.

See Section “Extensions to the C Language Family” in `gcc`.

The same example can be written using the newer extensions of naming the operands rather than using numbered arguments.

```

PROCEDURE Example (foo, bar: CARDINAL) : CARDINAL ;
VAR
  myout: CARDINAL ;
BEGIN
  ASM VOLATILE (
    "movl %[left],%%eax; addl %[right],%%eax; movl %%eax,%[output]"
    : [output] "=rm" (myout)           (* outputs *)
    : [left] "rm" (foo), [right] "rm" (bar)  (* inputs *)
    : "eax");                           (* we trash *)
  RETURN( myout )
END Example ;

```

Both examples generate exactly the same code. It is worth noting that the specifier “`rm`” indicates that the operand can be either a register or memory. Of course you must choose

an instruction which can take either, but this allows the compiler to make more efficient choices depending upon the optimization level.

## 2.19 Data type alignment

GNU Modula-2 allows you to specify alignment for types and variables. The syntax for alignment is to use the ISO pragma directives `<* bytealignment ( expression )` and `*>`. These directives can be used after type and variable declarations.

The ebnf of the alignment production is:

```
Alignment := [ ByteAlignment ] =:
ByteAlignment := '<*' AttributeExpression '*>' =:
AlignmentExpression := "(" ConstExpression ")" =:
```

The `Alignment` ebnf statement may be used during construction of types, records, record fields, arrays, pointers and variables. Below is an example of aligning a type so that the variable `bar` is aligned on a 1024 address.

```
MODULE align ;

TYPE
  foo = INTEGER <* bytealignment(1024) *> ;

VAR
  z : INTEGER ;
  bar: foo ;
BEGIN
END align.
```

The next example aligns a variable on a 1024 byte boundary.

```
MODULE align2 ;

VAR
  x : CHAR ;
  z : ARRAY [0..255] OF INTEGER <* bytealignment(1024) *> ;
BEGIN
END align2.
```

Here the example aligns a pointer on a 1024 byte boundary.

```
MODULE align4 ;

FROM SYSTEM IMPORT ADR ;
FROM libc IMPORT exit ;

VAR
  x : CHAR ;
  z : POINTER TO INTEGER <* bytealignment(1024) *> ;
BEGIN
  IF ADR(z) MOD 1024=0
  THEN
```

```

        exit(0)
    ELSE
        exit(1)
    END
END align4.

```

In example `align5` record field `y` is aligned on a 1024 byte boundary.

```

MODULE align5 ;

FROM SYSTEM IMPORT ADR ;
FROM libc IMPORT exit ;

TYPE
    rec = RECORD
        x: CHAR ;
        y: CHAR <* bytealignment(1024) *> ;
    END ;
VAR
    r: rec ;
BEGIN
    IF ADR(r.y) MOD 1024=0
    THEN
        exit(0)
    ELSE
        exit(1)
    END
END align5.

```

In the example below module `align6` declares `foo` as an array of 256 INTEGERS. The array `foo` is aligned on a 1024 byte boundary.

```

MODULE align6 ;

FROM SYSTEM IMPORT ADR ;
FROM libc IMPORT exit ;

TYPE
    foo = ARRAY [0..255] OF INTEGER <* bytealignment(1024) *> ;
VAR
    x : CHAR ;
    z : foo ;
BEGIN
    IF ADR(z) MOD 1024=0
    THEN
        exit(0)
    ELSE
        exit(1)
    END
END

```

```
END align6.
```

## 2.20 Packing data types

The pragma `<* bytealignment(0) *>` can be used to specify that the fields within a `RECORD` are to be packed. Currently this only applies to fields which are declared as subranges, ordinal types and enumerated types. Here is an example of how two subranges might be packed into a byte.

```
TYPE
  bits3c = [0..7] ;
  bits3i = [-4..3] ;

  byte = RECORD
    <* bytealignment(0) *>
    x: bits3c ;
    <* bitsunused(2) *>
    y: bits3i ;
  END ;
```

Notice that the user has specified that in between fields `x` and `y` there are two bits unused.

Now the user wishes to create a record with byte numbers zero and one occupied and then an `INTEGER32` field which is four byte aligned. In this case byte numbers two and three will be unused. The pragma `bytealignment` can be issued at the start of the record indicating the default alignment for the whole record and this can be overridden by individual fields if necessary.

```
rec = RECORD
  <* bytealignment (1) *> ;
  a, b: byte ;
  x: INTEGER32 <* bytealignment(4) *> ;
END ;
```

In the following example the user has specified that a record has two fields `p` and `q` but that there are three bytes unused between these fields.

```
header = RECORD
  <* bytealignment(1) *>
  p: byte ;
  <* bytesunused(3) *>
  q: byte ;
END ;
```

The pragma `<* bytesunused(x) *>` can only be used if the current field is on a byte boundary. There is also a `SYSTEM` pseudo procedure function `TBITSIZE(T)` which returns the minimum number of bits necessary to represent type `T`.

Another example of packing record bit fields is given below:

```
MODULE align21 ;

FROM libc IMPORT exit ;
```

```

TYPE
  colour = (red, blue, green, purple, white, black) ;

  soc = PACKEDSET OF colour ;

  rec = RECORD
    <* bytealignment(0) *>
    x: soc ;
    y: [-1..1] ;
  END ;

VAR
  r: rec ;
  v: CARDINAL ;
BEGIN
  v := SIZE(r) ;
  IF SIZE(r)#1
  THEN
    exit(1)
  END ;
  r.x := soc{blue} ;
  IF r.x#soc{blue}
  THEN
    exit(2)
  END
END align21.

```

Here we see that the total size of this record is one byte and consists of a six bit set type followed by a 2 bit integer subrange.

## 2.21 Accessing GNU Modula-2 Built-ins

This section describes the built-in constants and functions defined in GNU Modula-2. The following compiler constants can be accessed using the `__ATTRIBUTE__` `__BUILTIN__` keywords. These are not part of the Modula-2 language and they may differ depending upon the target architecture but they provide a method whereby common libraries can interface to a different underlying architecture.

The built-in constants are: `BITS_PER_UNIT`, `BITS_PER_WORD`, `BITS_PER_CHAR` and `UNITS_PER_WORD`. They are integrated into GNU Modula-2 by an extension to the `ConstFactor` rule:

```

ConstFactor := ConstQualidentOrSet | Number | ConstString |
  "(" ConstExpression ")" | "NOT" ConstFactor |
  ConstAttribute :=:

```

```

ConstAttribute := "__ATTRIBUTE__" "__BUILTIN__" "(" "(" Ident ")" ")" =:

```

Here is an example taken from the ISO library `SYSTEM.def`:

```

CONST
  BITS_PER_LOC    = __ATTRIBUTE__ __BUILTIN__ ((BITS_PER_UNIT)) ;
  LOC_SIZE        = __ATTRIBUTE__ __BUILTIN__ ((UNITS_PER_WORD)) ;

```

Built-in functions are transparent to the end user. All built-in functions are declared in DEFINITION MODULEs and are imported as and when required. Built-in functions are declared in definition modules by using the `__BUILTIN__` keyword. Here is a section of the ISO library `LongMath.def` which demonstrates this feature.

```

PROCEDURE __BUILTIN__ sqrt (x: LONGREAL): LONGREAL;
  (* Returns the square root of x *)

```

This indicates that the function `sqrt` will be implemented using the gcc built-in maths library. If gcc cannot utilize the built-in function (for example if the programmer requested the address of `sqrt`) then code is generated to call the alternative function implemented in the IMPLEMENTATION MODULE.

Sometimes a function exported from the DEFINITION MODULE will have a different name from the built-in function within gcc. In such cases the mapping between the GNU Modula-2 function name and the gcc name is expressed using the keywords `__ATTRIBUTE__ __BUILTIN__ ((Ident))`. For example the function `sqrt` in `LongMath.def` maps onto the gcc built-in function `sqrtl` and this is expressed as:

```

PROCEDURE __ATTRIBUTE__ __BUILTIN__ ((sqrtl)) sqrt
  (x: LONGREAL) : LONGREAL;
  (* Returns the positive square root of x *)

```

The following module `Builtins.def` enumerates the list of built-in functions which can be accessed in GNU Modula-2. It also serves to define the parameter and return value for each function:

```

DEFINITION MODULE Builtins ;

FROM SYSTEM IMPORT ADDRESS ;

(* Floating point intrinsic procedure functions. *)

PROCEDURE __BUILTIN__ isnanf (x: SHORTREAL) : INTEGER ;
PROCEDURE __BUILTIN__ isnan (x: REAL) : INTEGER ;
PROCEDURE __BUILTIN__ isnanl (x: LONGREAL) : INTEGER ;

PROCEDURE __BUILTIN__ isfinitef (x: SHORTREAL) : INTEGER ;
PROCEDURE __BUILTIN__ isfinite (x: REAL) : INTEGER ;
PROCEDURE __BUILTIN__ isfinitel (x: LONGREAL) : INTEGER ;

PROCEDURE __BUILTIN__ sinf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ sin (x: REAL) : REAL ;
PROCEDURE __BUILTIN__ sinl (x: LONGREAL) : LONGREAL ;

PROCEDURE __BUILTIN__ cosf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ cos (x: REAL) : REAL ;
PROCEDURE __BUILTIN__ cosl (x: LONGREAL) : LONGREAL ;

```

```

PROCEDURE __BUILTIN__ sqrtf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ sqrt (x: REAL) : REAL ;
PROCEDURE __BUILTIN__ sqrtl (x: LONGREAL) : LONGREAL ;

PROCEDURE __BUILTIN__ atan2f (x, y: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ atan2 (x, y: REAL) : REAL ;
PROCEDURE __BUILTIN__ atan2l (x, y: LONGREAL) : LONGREAL ;

PROCEDURE __BUILTIN__ fabsf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ fabs (x: REAL) : REAL ;
PROCEDURE __BUILTIN__ fabsl (x: LONGREAL) : LONGREAL ;

PROCEDURE __BUILTIN__ logf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ log (x: REAL) : REAL ;
PROCEDURE __BUILTIN__ logl (x: LONGREAL) : LONGREAL ;

PROCEDURE __BUILTIN__ expf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ exp (x: REAL) : REAL ;
PROCEDURE __BUILTIN__ expl (x: LONGREAL) : LONGREAL ;

PROCEDURE __BUILTIN__ log10f (x: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ log10 (x: REAL) : REAL ;
PROCEDURE __BUILTIN__ log10l (x: LONGREAL) : LONGREAL ;

PROCEDURE __BUILTIN__ exp10f (x: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ exp10 (x: REAL) : REAL ;
PROCEDURE __BUILTIN__ exp10l (x: LONGREAL) : LONGREAL ;

PROCEDURE __BUILTIN__ ilogbf (x: SHORTREAL) : INTEGER ;
PROCEDURE __BUILTIN__ ilogb (x: REAL) : INTEGER ;
PROCEDURE __BUILTIN__ ilogbl (x: LONGREAL) : INTEGER ;

PROCEDURE __BUILTIN__ huge_val () : REAL ;
PROCEDURE __BUILTIN__ huge_valf () : SHORTREAL ;
PROCEDURE __BUILTIN__ huge_vall () : LONGREAL ;

PROCEDURE __BUILTIN__ modf (x: REAL; VAR y: REAL) : REAL ;
PROCEDURE __BUILTIN__ modff (x: SHORTREAL;
                             VAR y: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ modfl (x: LONGREAL; VAR y: LONGREAL) : LONGREAL ;

PROCEDURE __BUILTIN__ signbit (r: REAL) : INTEGER ;
PROCEDURE __BUILTIN__ signbitf (s: SHORTREAL) : INTEGER ;
PROCEDURE __BUILTIN__ signbitl (l: LONGREAL) : INTEGER ;

PROCEDURE __BUILTIN__ nextafter (x, y: REAL) : REAL ;

```

```

PROCEDURE __BUILTIN__ nextafterf (x, y: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ nextafterl (x, y: LONGREAL) : LONGREAL ;

PROCEDURE __BUILTIN__ nexttoward (x: REAL; y: LONGREAL) : REAL ;
PROCEDURE __BUILTIN__ nexttowardf (x: SHORTREAL; y: LONGREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ nexttowardl (x, y: LONGREAL) : LONGREAL ;

PROCEDURE __BUILTIN__ scalbln (x: REAL; n: LONGINT) : REAL ;
PROCEDURE __BUILTIN__ scalblnf (x: SHORTREAL; n: LONGINT) : SHORTREAL ;
PROCEDURE __BUILTIN__ scalblnl (x: LONGREAL; n: LONGINT) : LONGREAL ;

PROCEDURE __BUILTIN__ scalbn (x: REAL; n: INTEGER) : REAL ;
PROCEDURE __BUILTIN__ scalbnf (x: SHORTREAL; n: INTEGER) : SHORTREAL ;
PROCEDURE __BUILTIN__ scalbnl (x: LONGREAL; n: INTEGER) : LONGREAL ;

PROCEDURE __BUILTIN__ isgreater (x, y: REAL) : INTEGER ;
PROCEDURE __BUILTIN__ isgreaterf (x, y: SHORTREAL) : INTEGER ;
PROCEDURE __BUILTIN__ isgreaterl (x, y: LONGREAL) : INTEGER ;

PROCEDURE __BUILTIN__ isgreaterequal (x, y: REAL) : INTEGER ;
PROCEDURE __BUILTIN__ isgreaterequalf (x, y: SHORTREAL) : INTEGER ;
PROCEDURE __BUILTIN__ isgreaterequall (x, y: LONGREAL) : INTEGER ;

PROCEDURE __BUILTIN__ isless (x, y: REAL) : INTEGER ;
PROCEDURE __BUILTIN__ islessf (x, y: SHORTREAL) : INTEGER ;
PROCEDURE __BUILTIN__ islessl (x, y: LONGREAL) : INTEGER ;

PROCEDURE __BUILTIN__ islessequal (x, y: REAL) : INTEGER ;
PROCEDURE __BUILTIN__ islessequalf (x, y: SHORTREAL) : INTEGER ;
PROCEDURE __BUILTIN__ islessequall (x, y: LONGREAL) : INTEGER ;

PROCEDURE __BUILTIN__ islessgreater (x, y: REAL) : INTEGER ;
PROCEDURE __BUILTIN__ islessgreaterf (x, y: SHORTREAL) : INTEGER ;
PROCEDURE __BUILTIN__ islessgreaterl (x, y: LONGREAL) : INTEGER ;

PROCEDURE __BUILTIN__ isunordered (x, y: REAL) : INTEGER ;
PROCEDURE __BUILTIN__ isunorderedf (x, y: SHORTREAL) : INTEGER ;
PROCEDURE __BUILTIN__ isunorderedl (x, y: LONGREAL) : INTEGER ;

PROCEDURE __BUILTIN__ iseqsig (x, y: REAL) : INTEGER ;
PROCEDURE __BUILTIN__ iseqsigf (x, y: SHORTREAL) : INTEGER ;
PROCEDURE __BUILTIN__ iseqsigl (x, y: LONGREAL) : INTEGER ;

PROCEDURE __BUILTIN__ isnormal (r: REAL) : INTEGER ;
PROCEDURE __BUILTIN__ isnormalf (s: SHORTREAL) : INTEGER ;
PROCEDURE __BUILTIN__ isnormall (l: LONGREAL) : INTEGER ;

```

```

PROCEDURE __BUILTIN__ isinf_sign (r: REAL) : INTEGER ;
PROCEDURE __BUILTIN__ isinf_signf (s: SHORTREAL) : INTEGER ;
PROCEDURE __BUILTIN__ isinf_signl (l: LONGREAL) : INTEGER ;

(* Complex arithmetic intrinsic procedure functions. *)

PROCEDURE __BUILTIN__ cabsf (z: SHORTCOMPLEX) : SHORTREAL ;
PROCEDURE __BUILTIN__ cabs (z: COMPLEX) : REAL ;
PROCEDURE __BUILTIN__ cabsl (z: LONGCOMPLEX) : LONGREAL ;

PROCEDURE __BUILTIN__ cargf (z: SHORTCOMPLEX) : SHORTREAL ;
PROCEDURE __BUILTIN__ carg (z: COMPLEX) : REAL ;
PROCEDURE __BUILTIN__ cargl (z: LONGCOMPLEX) : LONGREAL ;

PROCEDURE __BUILTIN__ conjf (z: SHORTCOMPLEX) : SHORTCOMPLEX ;
PROCEDURE __BUILTIN__ conj (z: COMPLEX) : COMPLEX ;
PROCEDURE __BUILTIN__ conjl (z: LONGCOMPLEX) : LONGCOMPLEX ;

PROCEDURE __BUILTIN__ cpowerf (base: SHORTCOMPLEX;
                               exp: SHORTREAL) : SHORTCOMPLEX ;
PROCEDURE __BUILTIN__ cpower (base: COMPLEX; exp: REAL) : COMPLEX ;
PROCEDURE __BUILTIN__ cpowerl (base: LONGCOMPLEX;
                               exp: LONGREAL) : LONGCOMPLEX ;

PROCEDURE __BUILTIN__ csqrtf (z: SHORTCOMPLEX) : SHORTCOMPLEX ;
PROCEDURE __BUILTIN__ csqrt (z: COMPLEX) : COMPLEX ;
PROCEDURE __BUILTIN__ csqrtl (z: LONGCOMPLEX) : LONGCOMPLEX ;

PROCEDURE __BUILTIN__ cexpf (z: SHORTCOMPLEX) : SHORTCOMPLEX ;
PROCEDURE __BUILTIN__ cexp (z: COMPLEX) : COMPLEX ;
PROCEDURE __BUILTIN__ cexpl (z: LONGCOMPLEX) : LONGCOMPLEX ;

PROCEDURE __BUILTIN__ clnf (z: SHORTCOMPLEX) : SHORTCOMPLEX ;
PROCEDURE __BUILTIN__ cln (z: COMPLEX) : COMPLEX ;
PROCEDURE __BUILTIN__ clnl (z: LONGCOMPLEX) : LONGCOMPLEX ;

PROCEDURE __BUILTIN__ csinf (z: SHORTCOMPLEX) : SHORTCOMPLEX ;
PROCEDURE __BUILTIN__ csin (z: COMPLEX) : COMPLEX ;
PROCEDURE __BUILTIN__ csinl (z: LONGCOMPLEX) : LONGCOMPLEX ;

PROCEDURE __BUILTIN__ ccosf (z: SHORTCOMPLEX) : SHORTCOMPLEX ;
PROCEDURE __BUILTIN__ ccos (z: COMPLEX) : COMPLEX ;
PROCEDURE __BUILTIN__ ccosl (z: LONGCOMPLEX) : LONGCOMPLEX ;

PROCEDURE __BUILTIN__ ctanf (z: SHORTCOMPLEX) : SHORTCOMPLEX ;
PROCEDURE __BUILTIN__ ctan (z: COMPLEX) : COMPLEX ;
PROCEDURE __BUILTIN__ ctanl (z: LONGCOMPLEX) : LONGCOMPLEX ;

```

```

PROCEDURE __BUILTIN__ carcsinf (z: SHORTCOMPLEX) : SHORTCOMPLEX ;
PROCEDURE __BUILTIN__ carcsin (z: COMPLEX) : COMPLEX ;
PROCEDURE __BUILTIN__ carcsinl (z: LONGCOMPLEX) : LONGCOMPLEX ;

PROCEDURE __BUILTIN__ carccosf (z: SHORTCOMPLEX) : SHORTCOMPLEX ;
PROCEDURE __BUILTIN__ carccos (z: COMPLEX) : COMPLEX ;
PROCEDURE __BUILTIN__ carccosl (z: LONGCOMPLEX) : LONGCOMPLEX ;

PROCEDURE __BUILTIN__ carctanf (z: SHORTCOMPLEX) : SHORTCOMPLEX ;
PROCEDURE __BUILTIN__ carctan (z: COMPLEX) : COMPLEX ;
PROCEDURE __BUILTIN__ carctanl (z: LONGCOMPLEX) : LONGCOMPLEX ;

(* memory and string intrinsic procedure functions *)

PROCEDURE __BUILTIN__ alloca (i: CARDINAL) : ADDRESS ;
PROCEDURE __BUILTIN__ memcpy (dest, src: ADDRESS;
                               nbytes: CARDINAL) : ADDRESS ;
PROCEDURE __BUILTIN__ index (s: ADDRESS; c: INTEGER) : ADDRESS ;
PROCEDURE __BUILTIN__ rindex (s: ADDRESS; c: INTEGER) : ADDRESS ;
PROCEDURE __BUILTIN__ memcmp (s1, s2: ADDRESS;
                               nbytes: CARDINAL) : INTEGER ;
PROCEDURE __BUILTIN__ memset (s: ADDRESS; c: INTEGER;
                               nbytes: CARDINAL) : ADDRESS ;
PROCEDURE __BUILTIN__ memmove (s1, s2: ADDRESS;
                               nbytes: CARDINAL) : ADDRESS ;
PROCEDURE __BUILTIN__ strcat (dest, src: ADDRESS) : ADDRESS ;
PROCEDURE __BUILTIN__ strncat (dest, src: ADDRESS;
                               nbytes: CARDINAL) : ADDRESS ;
PROCEDURE __BUILTIN__ strcpy (dest, src: ADDRESS) : ADDRESS ;
PROCEDURE __BUILTIN__ strncpy (dest, src: ADDRESS;
                               nbytes: CARDINAL) : ADDRESS ;
PROCEDURE __BUILTIN__ strcmp (s1, s2: ADDRESS) : INTEGER ;
PROCEDURE __BUILTIN__ strncmp (s1, s2: ADDRESS;
                               nbytes: CARDINAL) : INTEGER ;
PROCEDURE __BUILTIN__ strlen (s: ADDRESS) : INTEGER ;
PROCEDURE __BUILTIN__ strstr (haystack, needle: ADDRESS) : ADDRESS ;
PROCEDURE __BUILTIN__ strpbrk (s, accept: ADDRESS) : ADDRESS ;
PROCEDURE __BUILTIN__ strspn (s, accept: ADDRESS) : CARDINAL ;
PROCEDURE __BUILTIN__ strcspn (s, accept: ADDRESS) : CARDINAL ;
PROCEDURE __BUILTIN__ strchr (s: ADDRESS; c: INTEGER) : ADDRESS ;
PROCEDURE __BUILTIN__ strrchr (s: ADDRESS; c: INTEGER) : ADDRESS ;

PROCEDURE __BUILTIN__ clz (value: CARDINAL) : INTEGER ;
PROCEDURE __BUILTIN__ clzll (value: LONGCARD) : INTEGER ;
PROCEDURE __BUILTIN__ ctz (value: CARDINAL) : INTEGER ;
PROCEDURE __BUILTIN__ ctzll (value: LONGCARD) : INTEGER ;

```

```

(*
  longjmp - this GCC builtin restricts the val to always 1.
*)
(* do not use these two builtins, as gcc, only really
   anticipates that the Ada front end should use them
   and it only uses them in its runtime exception handling.
   We leave them here in the hope that someday they will
   behave more like their libc counterparts.  *)

PROCEDURE __BUILTIN__ longjmp (env: ADDRESS; val: INTEGER) ;
PROCEDURE __BUILTIN__ setjmp (env: ADDRESS) : INTEGER ;

(*
  frame_address - returns the address of the frame.
                  The current frame is obtained if level is 0,
                  the next level up if level is 1 etc.
*)

PROCEDURE __BUILTIN__ frame_address (level: CARDINAL) : ADDRESS ;

(*
  return_address - returns the return address of function.
                  The current function return address is
                  obtained if level is 0,
                  the next level up if level is 1 etc.
*)

PROCEDURE __BUILTIN__ return_address (level: CARDINAL) : ADDRESS ;

(*
  alloca_trace - this is a no-op which is used for internal debugging.
*)

PROCEDURE alloca_trace (returned: ADDRESS; nBytes: CARDINAL) : ADDRESS ;

END Builtins.

```

Although this module exists and will result in the generation of in-line code if optimization flags are passed to GNU Modula-2, users are advised to utilize the same functions from more generic libraries. The built-in mechanism will be applied to these generic libraries where appropriate. Note for the mathematical routines to be in-lined you need to specify the ‘-ffast-math -O’ options.

## 2.22 The PIM system module

```

DEFINITION MODULE SYSTEM ;

EXPORT QUALIFIED BITS_PER_BYTE, BYTES_PER_WORD,
    ADDRESS, WORD, BYTE, C_SIZE_T, C_SIZE_T, COFF_T, CARDINAL64, (*
    Target specific data types. *)
    ADR, T_SIZE, ROTATE, SHIFT, THROW, T_BIT_SIZE ;
    (* SIZE is also exported if -fpim2 is used. *)

CONST
    BITS_PER_BYTE = __ATTRIBUTE__ __BUILTIN__ ((BITS_PER_UNIT)) ;
    BYTES_PER_WORD = __ATTRIBUTE__ __BUILTIN__ ((UNITS_PER_WORD)) ;

(* Note that the full list of system and sized datatypes include:
    LOC, WORD, BYTE, ADDRESS,

    (and the non language standard target types)

    INTEGER8, INTEGER16, INTEGER32, INTEGER64,
    CARDINAL8, CARDINAL16, CARDINAL32, CARDINAL64,
    WORD16, WORD32, WORD64, BITSET8, BITSET16,
    BITSET32, REAL32, REAL64, REAL128, COMPLEX32,
    COMPLEX64, COMPLEX128, C_SIZE_T, C_SIZE_T.

    Also note that the non-standard data types will
    move into another module in the future. *)

(* The following types are supported on this target:
TYPE
    (* Target specific data types. *)
*)

(*
    all the functions below are declared internally to gm2
    =====

PROCEDURE ADR (VAR v: <anytype>): ADDRESS;
    (* Returns the address of variable v. *)

PROCEDURE SIZE (v: <type>) : ZType;
    (* Returns the number of BYTES used to store a v of
    any specified <type>. Only available if -fpim2 is used.
    *)

```

```

PROCEDURE TSIZE (<type>) : CARDINAL;
  (* Returns the number of BYTES used to store a value of the
     specified <type>.
  *)

PROCEDURE ROTATE (val: <a set type>;
                  num: INTEGER): <type of first parameter>;
  (* Returns a bit sequence obtained from val by rotating up/right
     or down/right by the absolute value of num. The direction is
     down/right if the sign of num is negative, otherwise the direction
     is up/left.
  *)

PROCEDURE SHIFT (val: <a set type>;
                 num: INTEGER): <type of first parameter>;
  (* Returns a bit sequence obtained from val by shifting up/left
     or down/right by the absolute value of num, introducing
     zeros as necessary. The direction is down/right if the sign of
     num is negative, otherwise the direction is up/left.
  *)

PROCEDURE THROW (i: INTEGER) <* noreturn *> ;
  (*
     THROW is a GNU extension and was not part of the PIM or ISO
     standards. It throws an exception which will be caught by the
     EXCEPT block (assuming it exists). This is a compiler builtin
     function which interfaces to the GCC exception handling runtime
     system.
     GCC uses the term throw, hence the naming distinction between
     the GCC builtin and the Modula-2 runtime library procedure Raise.
     The later library procedure Raise will call SYSTEM.THROW after
     performing various housekeeping activities.
  *)

PROCEDURE TBITSIZE (<type>) : CARDINAL ;
  (* Returns the minimum number of bits necessary to represent
     <type>. This procedure function is only useful for determining
     the number of bits used for any type field within a packed RECORD.
     It is not particularly useful elsewhere since <type> might be
     optimized for speed, for example a BOOLEAN could occupy a WORD.
  *)

(* The following procedures are invoked by GNU Modula-2 to
   shift non word sized set types. They are not strictly part
   of the core PIM Modula-2, however they are used
   to implement the SHIFT procedure defined above,

```

which are in turn used by the Logitech compatible libraries.

Users will access these procedures by using the procedure SHIFT above and GNU Modula-2 will map SHIFT onto one of the following procedures.

\*)

(\*

ShiftVal - is a runtime procedure whose job is to implement the SHIFT procedure of ISO SYSTEM. GNU Modula-2 will inline a SHIFT of a single WORD sized set and will only call this routine for larger sets.

\*)

```
PROCEDURE ShiftVal (VAR s, d: ARRAY OF BITSET;
                   SetSizeInBits: CARDINAL;
                   ShiftCount: INTEGER) ;
```

(\*

ShiftLeft - performs the shift left for a multi word set. This procedure might be called by the back end of GNU Modula-2 depending whether amount is known at compile time.

\*)

```
PROCEDURE ShiftLeft (VAR s, d: ARRAY OF BITSET;
                    SetSizeInBits: CARDINAL;
                    ShiftCount: CARDINAL) ;
```

(\*

ShiftRight - performs the shift left for a multi word set. This procedure might be called by the back end of GNU Modula-2 depending whether amount is known at compile time.

\*)

```
PROCEDURE ShiftRight (VAR s, d: ARRAY OF BITSET;
                     SetSizeInBits: CARDINAL;
                     ShiftCount: CARDINAL) ;
```

(\*

RotateVal - is a runtime procedure whose job is to implement the ROTATE procedure of ISO SYSTEM. GNU Modula-2 will inline a ROTATE of a single WORD (or less) sized set and will only call this routine for larger

```

sets.

*)

PROCEDURE RotateVal (VAR s, d: ARRAY OF BITSET;
                    SetSizeInBits: CARDINAL;
                    RotateCount: INTEGER) ;

(*
  RotateLeft - performs the rotate left for a multi word set.
  This procedure might be called by the back end of
  GNU Modula-2 depending whether amount is known at
  compile time.
*)

PROCEDURE RotateLeft (VAR s, d: ARRAY OF BITSET;
                     SetSizeInBits: CARDINAL;
                     RotateCount: CARDINAL) ;

(*
  RotateRight - performs the rotate right for a multi word set.
  This procedure might be called by the back end of
  GNU Modula-2 depending whether amount is known at
  compile time.
*)

PROCEDURE RotateRight (VAR s, d: ARRAY OF BITSET;
                      SetSizeInBits: CARDINAL;
                      RotateCount: CARDINAL) ;

END SYSTEM.
```

The different dialects of Modula-2 PIM-[234] and ISO Modula-2 declare the function `SIZE` in different places. PIM-[34] and ISO Modula-2 declare `SIZE` as a pervasive function (declared in the base module). PIM-2 defined `SIZE` in the `SYSTEM` module (as shown above).

GNU Modula-2 allows users to specify the dialect of Modula-2 by using the `-fiso` and `-fpim2` command line switches.

The data types `CSIZE_T`, `CSSIZE_T` and `COFF_T` are also exported from the `SYSTEM` module. The type `CSIZE_T` is unsigned and is mapped onto the target C data type `size_t` whereas the type `CSSIZE_T` is mapped onto the signed C data type `ssize_t`. The default size for the signed type `COFF_T` is the same as `CSSIZE_T` and this can be overridden by the `-fm2-file-offset-bits=` command line option.

It is anticipated that these should only be used to provide cross platform definition modules for C libraries.

There are also a variety of fixed sized **INTEGER** and **CARDINAL** types. The variety of the fixed sized types will depend upon the target architecture.

## 2.23 The ISO system module

```
DEFINITION MODULE SYSTEM;
```

```
  (* Gives access to system programming facilities that are probably
     non portable. *)
```

```
  (* The constants and types define underlying properties of storage *)
```

```
EXPORT QUALIFIED BITS_PER_LOC, LOC_SIZE, WORD_SIZE, ADDRESS_SIZE, C_SIZE_T, C_SIZE_T, COFF_T, (*
    Target specific data types. *)
    ADD_ADDR, SUB_ADDR, DIV_ADDR, MAKE_ADDR, ADDR, ROTATE,
    SHIFT, CAST, T_SIZE,
```

```
    (* Internal GM2 compiler functions *)
    ShiftVal, ShiftLeft, ShiftRight,
    RotateVal, RotateLeft, RotateRight,
    THROW, T_BITS_SIZE ;
```

```
CONST
```

```
    (* <implementation-defined constant> ; *)
    BITS_PER_LOC      = __ATTRIBUTE__ __BUILTIN__ ((BITS_PER_UNIT)) ;
    (* <implementation-defined constant> ; *)
    LOC_SIZE          = __ATTRIBUTE__ __BUILTIN__ ((UNITS_PER_WORD)) ;
    (* <implementation-defined constant> ; *)
    LOC_SIZE_BYTE     = 8 DIV BITS_PER_LOC ;
```

```
(* Note that the full list of system and sized datatypes include:
    LOC, WORD, BYTE, ADDRESS,
```

```
(and the non language standard target types)
```

```
    INTEGER8, INTEGER16, INTEGER32, INTEGER64,
    CARDINAL8, CARDINAL16, CARDINAL32, CARDINAL64,
    WORD16, WORD32, WORD64, BITSET8, BITSET16,
    BITSET32, REAL32, REAL64, REAL128, COMPLEX32,
    COMPLEX64, COMPLEX128, C_SIZE_T, C_SIZE_T.
```

```
Also note that the non-standard data types will
move into another module in the future. *)
```

```
(*
```

```
    All the data types and procedures below are declared internally.
```

```

=====

TYPE
  (* Target specific data types.  *)

TYPE
  LOC; (* A system basic type. Values are the uninterpreted
        contents of the smallest addressable unit of storage *)
  ADDRESS = POINTER TO LOC;
  WORD = ARRAY [0 .. LOCSPERWORD-1] OF LOC;

  (* BYTE and LOCSPERBYTE are provided if appropriate for machine *)

TYPE
  BYTE = ARRAY [0 .. LOCSPERBYTE-1] OF LOC;

PROCEDURE ADDADR (addr: ADDRESS; offset: CARDINAL): ADDRESS;
  (* Returns address given by (addr + offset), or may raise
     an exception if this address is not valid.
  *)

PROCEDURE SUBADR (addr: ADDRESS; offset: CARDINAL): ADDRESS;
  (* Returns address given by (addr - offset), or may raise an
     exception if this address is not valid.
  *)

PROCEDURE DIFADR (addr1, addr2: ADDRESS): INTEGER;
  (* Returns the difference between addresses (addr1 - addr2),
     or may raise an exception if the arguments are invalid
     or address space is non-contiguous.
  *)

PROCEDURE MAKEADR (high: <some type>; ...): ADDRESS;
  (* Returns an address constructed from a list of values whose
     types are implementation-defined, or may raise an
     exception if this address is not valid.

     In GNU Modula-2, MAKEADR can take any number of arguments
     which are mapped onto the type ADDRESS. The first parameter
     maps onto the high address bits and subsequent parameters map
     onto lower address bits. For example:

     a := MAKEADR(BYTE(0FEH), BYTE(0DCH), BYTE(0BAH), BYTE(098H),
                  BYTE(076H), BYTE(054H), BYTE(032H), BYTE(010H)) ;

     then the value of, a, on a 64 bit machine is: 0FEDCBA9876543210H
  *)

```

The parameters do not have to be the same type, but constants `_must_` be typed.

\*)

```
PROCEDURE ADR (VAR v: <anytype>): ADDRESS;
```

(\* Returns the address of variable v. \*)

```
PROCEDURE ROTATE (val: <a packedset type>;
                  num: INTEGER): <type of first parameter>;
```

(\* Returns a bit sequence obtained from val by rotating up/right or down/right by the absolute value of num. The direction is down/right if the sign of num is negative, otherwise the direction is up/left.

\*)

```
PROCEDURE SHIFT (val: <a packedset type>;
                 num: INTEGER): <type of first parameter>;
```

(\* Returns a bit sequence obtained from val by shifting up/left or down/right by the absolute value of num, introducing zeros as necessary. The direction is down/right if the sign of num is negative, otherwise the direction is up/left.

\*)

```
PROCEDURE CAST (<targettype>; val: <anytype>): <targettype>;
```

(\* CAST is a type transfer function. Given the expression denoted by val, it returns a value of the type <targettype>. An invalid value for the target value or a physical address alignment problem may raise an exception.

\*)

```
PROCEDURE TSIZE (<type>; ... ): CARDINAL;
```

(\* Returns the number of LOCS used to store a value of the specified <type>. The extra parameters, if present, are used to distinguish variants in a variant record.

\*)

```
PROCEDURE THROW (i: INTEGER) <* noreturn *> ;
```

(\*

THROW is a GNU extension and was not part of the PIM or ISO standards. It throws an exception which will be caught by the EXCEPT block (assuming it exists). This is a compiler builtin function which interfaces to the GCC exception handling runtime system.

GCC uses the term throw, hence the naming distinction between the GCC builtin and the Modula-2 runtime library procedure Raise. The later library procedure Raise will call SYSTEM.THROW after performing various housekeeping activities.

```

*)

PROCEDURE TBITSIZE (<type>) : CARDINAL ;
  (* Returns the minimum number of bits necessary to represent
     <type>. This procedure function is only useful for determining
     the number of bits used for any type field within a packed RECORD.
     It is not particularly useful elsewhere since <type> might be
     optimized for speed, for example a BOOLEAN could occupy a WORD.
  *)
*)

(* The following procedures are invoked by GNU Modula-2 to
   shift non word set types. They are not part of ISO Modula-2
   but are used to implement the SHIFT procedure defined above. *)

(*
   ShiftVal - is a runtime procedure whose job is to implement
               the SHIFT procedure of ISO SYSTEM. GNU Modula-2 will
               inline a SHIFT of a single WORD sized set and will only
               call this routine for larger sets.
  *)

PROCEDURE ShiftVal (VAR s, d: ARRAY OF BITSET;
                   SetSizeInBits: CARDINAL;
                   ShiftCount: INTEGER) ;

(*
   ShiftLeft - performs the shift left for a multi word set.
               This procedure might be called by the back end of
               GNU Modula-2 depending whether amount is known at
               compile time.
  *)

PROCEDURE ShiftLeft (VAR s, d: ARRAY OF BITSET;
                    SetSizeInBits: CARDINAL;
                    ShiftCount: CARDINAL) ;

(*
   ShiftRight - performs the shift left for a multi word set.
                This procedure might be called by the back end of
                GNU Modula-2 depending whether amount is known at
                compile time.
  *)

PROCEDURE ShiftRight (VAR s, d: ARRAY OF BITSET;

```

```

        SetSizeInBits: CARDINAL;
        ShiftCount: CARDINAL) ;

(*
    RotateVal - is a runtime procedure whose job is to implement
                the ROTATE procedure of ISO SYSTEM. GNU Modula-2 will
                inline a ROTATE of a single WORD (or less)
                sized set and will only call this routine for larger
                sets.
*)

PROCEDURE RotateVal (VAR s, d: ARRAY OF BITSET;
                    SetSizeInBits: CARDINAL;
                    RotateCount: INTEGER) ;

(*
    RotateLeft - performs the rotate left for a multi word set.
                This procedure might be called by the back end of
                GNU Modula-2 depending whether amount is known at
                compile time.
*)

PROCEDURE RotateLeft (VAR s, d: ARRAY OF BITSET;
                     SetSizeInBits: CARDINAL;
                     RotateCount: CARDINAL) ;

(*
    RotateRight - performs the rotate right for a multi word set.
                 This procedure might be called by the back end of
                 GNU Modula-2 depending whether amount is known at
                 compile time.
*)

PROCEDURE RotateRight (VAR s, d: ARRAY OF BITSET;
                      SetSizeInBits: CARDINAL;
                      RotateCount: CARDINAL) ;

END SYSTEM.
```

The data types `CSIZE_T`, `CSSIZE_T` and `COFF_T` are also exported from the `SYSTEM` module. The type `CSIZE_T` is unsigned and is mapped onto the target C data type `size_t` whereas the type `CSSIZE_T` is mapped onto the signed C data type `ssize_t`. The default

size for the signed type `COFF_T` is the same as `CSSIZE_T` and this can be overridden by the `-fm2-file-offset-bits=` command line option.

It is anticipated that these should only be used to provide cross platform definition modules for C libraries.

There are also a variety of fixed sized `INTEGER` and `CARDINAL` types. The variety of the fixed sized types will depend upon the target architecture.

## 2.24 Release map

GNU Modula-2 is now part of GCC and therefore will adopt the GCC release schedule. It is intended that GNU Modula-2 implement more of the GCC builtins (vararg access) and GCC features.

There is an intention to implement the ISO generics and the M2R10 dialect of Modula-2. It will also implement all language changes. If you wish to see something different please email [gm2@nongnu.org](mailto:gm2@nongnu.org) with your ideas.

## 2.25 Documentation

The GNU Modula-2 documentation is available online at <https://gcc.gnu.org/onlinedocs/> in the PDF, info, and HTML file formats.

## 2.26 Regression tests for gm2 in the repository

The regression testsuite can be run from the gcc build directory:

```
$ cd build-gcc
$ make check -j 24
```

which runs the complete testsuite for all compilers using 24 parallel invocations of the compiler. Individual language testsuites can be run by specifying the language, for example the Modula-2 testsuite can be run using:

```
$ cd build-gcc
$ make check-m2 -j 24
```

Finally the results of the testsuite can be emailed to the gcc-testresults (<https://gcc.gnu.org/lists.html>) list using the `test_summary` script found in the gcc source tree:

```
$ 'directory to the sources'/contrib/test_summary
```

## 2.27 Limitations

The Logitech compatibility library is incomplete. The primary modules for this platform exist, though for a comprehensive list of completed modules please check the documentation.

## 2.28 Objectives

- The intention of GNU Modula-2 is to provide a production Modula-2 front end to GCC.
- It should support all Niklaus Wirth PIM Dialects [234] and also ISO Modula-2 including a re-implementation of all the ISO modules.
- There should be an easy interface to C.

- Exploit the features of GCC.
- Listen to the requests of the users.

## 2.29 FAQ

### 2.29.1 Why use the C++ exception mechanism in GCC, rather than a bespoke Modula-2 mechanism?

The C++ mechanism is tried and tested, it also provides GNU Modula-2 with the ability to link with C++ modules and via swig it can raise Python exceptions.

## 2.30 Community

You can subscribe to the GNU Modula-2 mailing by sending an email to: [gm2-subscribe@nongnu.org](mailto:gm2-subscribe@nongnu.org) or by <https://lists.nongnu.org/mailman/listinfo/gm2>. The mailing list contents can be viewed <https://lists.gnu.org/archive/html/gm2/>.

## 2.31 Other languages for GCC

These exist and can be found on the frontends web page on the GCC web site (<https://gcc.gnu.org/frontends.html>).

## 2.32 License of GNU Modula-2

GNU Modula-2 is free software, the compiler is held under the GPL v3 <http://www.gnu.org/licenses/gpl-3.0.txt>, its libraries (pim, iso and Logitech compatible) are under the GPL v3 with the GCC run time library exception clause.

Under Section 7 of GPL version 3, you are granted additional permissions described in the GCC Runtime Library Exception, version 3.1, as published by the Free Software Foundation.

You should have received a copy of the GNU General Public License and a copy of the GCC Runtime Library Exception along with this program; see the files COPYING3 and COPYING.RUNTIME respectively. If not, see [<http://www.gnu.org/licenses/>](http://www.gnu.org/licenses/).

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Version 3, 29 June 2007

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## Preamble

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Some devices are designed to deny users access to install or run modified versions of the software inside them, although the manufacturer can do so. This is fundamentally incompatible with the aim of protecting users' freedom to change the software. The systematic pattern of such abuse occurs in the area of products for individuals to use, which is precisely where it is most unacceptable. Therefore, we have designed this version of the GPL to prohibit the practice for those products. If such problems arise substantially in other domains, we stand ready to extend this provision to those domains in future versions of the GPL, as needed to protect the freedom of users.

Finally, every program is threatened constantly by software patents. States should not allow patents to restrict development and use of software on general-purpose computers, but in those that do, we wish to avoid the special danger that patents applied to a free program could make it effectively proprietary. To prevent this, the GPL assures that patents cannot be used to render the program non-free.

The precise terms and conditions for copying, distribution and modification follow.

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### 1. Source Code.

The “source code” for a work means the preferred form of the work for making modifications to it. “Object code” means any non-source form of a work.

A “Standard Interface” means an interface that either is an official standard defined by a recognized standards body, or, in the case of interfaces specified for a particular programming language, one that is widely used among developers working in that language.

The “System Libraries” of an executable work include anything, other than the work as a whole, that (a) is included in the normal form of packaging a Major Component, but which is not part of that Major Component, and (b) serves only to enable use of the work with that Major Component, or to implement a Standard Interface for which an implementation is available to the public in source code form. A “Major Component”, in this context, means a major essential component (kernel, window system, and so on) of the specific operating system (if any) on which the executable work runs, or a compiler used to produce the work, or an object code interpreter used to run it.

The “Corresponding Source” for a work in object code form means all the source code needed to generate, install, and (for an executable work) run the object code and to modify the work, including scripts to control those activities. However, it does not include the work’s System Libraries, or general-purpose tools or generally available free programs which are used unmodified in performing those activities but which are not part of the work. For example, Corresponding Source includes interface definition files associated with source files for the work, and the source code for shared libraries and dynamically linked subprograms that the work is specifically designed to require, such as by intimate data communication or control flow between those subprograms and other parts of the work.

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```
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```

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### 3 EBNF of GNU Modula-2

This chapter contains the EBNF of GNU Modula-2. This grammar currently supports both PIM and ISO dialects. The rules here are automatically extracted from the crammer files in GNU Modula-2 and serve to document the syntax of the extensions described earlier and how they fit in with the base language.

Note that the first six productions are built into the lexical analysis phase.

```

Ident := is a builtin and checks for an identifier
      =:

Integer := is a builtin and checks for an integer
        =:

Real := is a builtin and checks for an real constant
      =:

string := is a builtin and checks for an string constant
        =:

FileUnit := ( DefinitionModule |
              ImplementationOrProgramModule )
          =:

ProgramModule := 'MODULE' Ident [ Priority ] ';' {
  Import } Block Ident '.'
              =:

ImplementationModule := 'IMPLEMENTATION' 'MODULE' Ident
                      [ Priority ] ';' { Import
                                   } Block
                      Ident '.'
                      =:

ImplementationOrProgramModule := ImplementationModule |
                                ProgramModule
                                =:

Number := Integer | Real
        =:

Qualident := Ident { '.' Ident }
          =:

ConstantDeclaration := Ident '=' ConstExpression
                    =:

ConstExpression := SimpleConstExpr [ Relation SimpleConstExpr ]
                =:

Relation := '=' | '#' | '<>' | '<' | '<=' |
           '>' | '>=' | 'IN'
          =:

SimpleConstExpr := UnaryOrConstTerm { AddOperator
                                     ConstTerm }
                =:

UnaryOrConstTerm := '+' ConstTerm |

```

```

        '-' ConstTerm |
        ConstTerm
    =:
AddOperator := '+' | '-' | 'OR'
    =:
ConstTerm := ConstFactor { MulOperator ConstFactor }
    =:
MulOperator := '*' | '/' | 'DIV' | 'MOD' |
    'REM' | 'AND' | '&'
    =:
ConstFactor := Number | ConstString |
    ConstSetOrQualidentOrFunction |
    '(' ConstExpression ')' |
    'NOT' ConstFactor |
    ConstAttribute
    =:
ConstString := string
    =:
ComponentElement := ConstExpression [ '..' ConstExpression ]
    =:
ComponentValue := ComponentElement [ 'BY' ConstExpression ]
    =:
ArraySetRecordValue := ComponentValue { ',' ComponentValue }
    =:
Constructor := '{' [ ArraySetRecordValue ] '}'
    =:
ConstSetOrQualidentOrFunction := Constructor |
    Qualident [ Constructor |
    ConstActualParameters ]
    =:
ConstActualParameters := '(' [ ExpList ] ')'
    =:
ConstAttribute := '__ATTRIBUTE__' '__BUILTIN__' '('
    '(' ConstAttributeExpression ')'
    ')'
    =:
ConstAttributeExpression := Ident | '<' Qualident
    ',' Ident '>'
    =:
ByteAlignment := '<*' AttributeExpression '*>'
    =:
Alignment := [ ByteAlignment ]
    =:
TypeDeclaration := Ident '=' Type Alignment

```

```

=:
Type := SimpleType | ArrayType | RecordType |
      SetType | PointerType | ProcedureType
=:
SimpleType := Qualident [ SubrangeType ] |
      Enumeration | SubrangeType
=:
Enumeration := '(' IdentList ')'
=:
IdentList := Ident { ',' Ident }
=:
SubrangeType := '[' ConstExpression '..' ConstExpression
              ']'
=:
ArrayType := 'ARRAY' SimpleType { ',' SimpleType }
           'OF' Type
=:
RecordType := 'RECORD' [ DefaultRecordAttributes ]
            FieldListSequence 'END'
=:
DefaultRecordAttributes := '<*' AttributeExpression
                        '*>'
=:
RecordFieldPragma := [ '<*' FieldPragmaExpression {
                      ',' FieldPragmaExpression } '*>' ]
=:
FieldPragmaExpression := Ident [ '(' ConstExpression
                               ')' ]
=:
AttributeExpression := Ident '(' ConstExpression ')'
=:
FieldListSequence := FieldListStatement { ';' FieldListStatement }
=:
FieldListStatement := [ FieldList ]
=:
FieldList := IdentList ':' Type RecordFieldPragma |
            'CASE' CaseTag 'OF' Variant { '|' Variant }
            [ 'ELSE' FieldListSequence ] 'END'
=:
TagIdent := [ Ident ]
=:
CaseTag := TagIdent [ ':' Qualident ]

```

```

      =:
Variant := [ VariantCaseLabelList ':' FieldListSequence ]
      =:
VariantCaseLabelList := VariantCaseLabels { ',', VariantCaseLabels }
      =:
VariantCaseLabels := ConstExpression [ '..' ConstExpression ]
      =:
CaseLabelList := CaseLabels { ',', CaseLabels }
      =:
CaseLabels := ConstExpression [ '..' ConstExpression ]
      =:
SetType := ( 'SET' | 'PACKEDSET' ) 'OF' SimpleType
      =:
PointerType := 'POINTER' 'TO' Type
      =:
ProcedureType := 'PROCEDURE' [ FormalTypeList ]
      =:
FormalTypeList := '(' ( '(' FormalReturn |
                        ProcedureParameters ')' FormalReturn )
      =:
FormalReturn := [ ':' OptReturnType ]
      =:
OptReturnType := '[' Qualident ']' |
                Qualident
      =:
ProcedureParameters := ProcedureParameter { ',', ProcedureParameter }
      =:
ProcedureParameter := '...' | 'VAR' FormalType |
                      FormalType
      =:
VarIdent := Ident [ '[' ConstExpression ']' ]
      =:
VariableDeclaration := VarIdentList ':' Type Alignment
      =:
VarIdentList := VarIdent { ',', VarIdent }
      =:
Designator := Qualident { SubDesignator }
      =:
SubDesignator := '.' Ident | '[' ExpList ']' |
                '^'
      =:
ExpList := Expression { ',', Expression }

```

```

=:
Expression := SimpleExpression [ Relation SimpleExpression ]
=:
SimpleExpression := [ '+' | '-' ] Term { AddOperator
                                     Term }
=:
Term := Factor { MulOperator Factor }
=:
Factor := Number | string | SetOrDesignatorOrFunction |
         '(' Expression ')' |
         'NOT' Factor | ConstAttribute
=:
SetOrDesignatorOrFunction := ( Qualident [ Constructor |
                                     SimpleDes
                                     [ ActualParameters ] ] |
                               Constructor )
=:
SimpleDes := { '.' Ident | '[' ExpList ']' |
              '^' }
=:
ActualParameters := '(' [ ExpList ] ')'
=:
Statement := [ AssignmentOrProcedureCall |
              IfStatement | CaseStatement |
              WhileStatement | RepeatStatement |
              LoopStatement | ForStatement |
              WithStatement | AsmStatement |
              'EXIT' | 'RETURN' [ Expression ] |
              RetryStatement ]
=:
RetryStatement := 'RETRY'
=:
AssignmentOrProcedureCall := Designator ( ':' Expression |
                                     ActualParameters |
                                     )
=:
StatementSequence := Statement { ';' Statement }
=:
IfStatement := 'IF' Expression 'THEN' StatementSequence
              { 'ELSIF' Expression 'THEN' StatementSequence }
              [ 'ELSE' StatementSequence ] 'END'
=:
CaseStatement := 'CASE' Expression 'OF' Case { '|'
                                              Case }

```

```

        [ 'ELSE' StatementSequence ] 'END'
    =:
Case := [ CaseLabelList ':' StatementSequence ]
    =:
WhileStatement := 'WHILE' Expression 'DO' StatementSequence
    'END'
    =:
RepeatStatement := 'REPEAT' StatementSequence 'UNTIL'
    Expression
    =:
ForStatement := 'FOR' Ident ':= ' Expression 'TO' Expression
    [ 'BY' ConstExpression ] 'DO' StatementSequence
    'END'
    =:
LoopStatement := 'LOOP' StatementSequence 'END'
    =:
WithStatement := 'WITH' Designator 'DO' StatementSequence
    'END'
    =:
ProcedureDeclaration := ProcedureHeading ';' ( ProcedureBlock
                                                Ident
                                                )
    =:
DefineBuiltinProcedure := [ '__ATTRIBUTE__' '__BUILTIN__'
    '(' '(' Ident ')' ')' |
    '__INLINE__' ]
    =:
ProcedureHeading := 'PROCEDURE' DefineBuiltinProcedure
    ( Ident [ FormalParameters ] AttributeNoReturn )
    =:
AttributeNoReturn := [ '<*' Ident '*>' ]
    =:
AttributeUnused := [ '<*' Ident '*>' ]
    =:
Builtin := [ '__BUILTIN__' | '__INLINE__' ]
    =:
DefProcedureHeading := 'PROCEDURE' Builtin ( Ident
                                                [ DefFormalParameters ]
                                                AttributeNoReturn )
    =:
ProcedureBlock := { Declaration } [ 'BEGIN' BlockBody ]
    'END'

```

```

      =:
Block := { Declaration } InitialBlock FinalBlock
      'END'
      =:
InitialBlock := [ 'BEGIN' BlockBody ]
      =:
FinalBlock := [ 'FINALLY' BlockBody ]
      =:
BlockBody := NormalPart [ 'EXCEPT' ExceptionalPart ]
      =:
NormalPart := StatementSequence
      =:
ExceptionalPart := StatementSequence
      =:
Declaration := 'CONST' { ConstantDeclaration ';' } |
              'TYPE' { TypeDeclaration ';' } |
              'VAR' { VariableDeclaration ';' } |
              ProcedureDeclaration ';' |
              ModuleDeclaration ';'
      =:
DefFormalParameters := '(' [ DefMultiFPSection ] ')'
                    FormalReturn
                    =:
DefMultiFPSection := DefExtendedFP |
                    FPSection [ ';' DefMultiFPSection ]
                    =:
FormalParameters := '(' [ MultiFPSection ] ')' FormalReturn
                    =:
MultiFPSection := ExtendedFP | FPSection [ ';' MultiFPSection ]
                    =:
FPSection := NonVarFPSection | VarFPSection
                    =:
DefExtendedFP := DefOptArg | '...'
                    =:
ExtendedFP := OptArg | '...'
                    =:
VarFPSection := 'VAR' IdentList ':' FormalType [ AttributeUnused ]
                    =:
NonVarFPSection := IdentList ':' FormalType [ AttributeUnused ]
                    =:
OptArg := '[' Ident ':' FormalType [ '=' ConstExpression ]
        ']'

```

```

=:
DefOptArg := '[' Ident ':' FormalType '=' ConstExpression
            ']'
=:
FormalType := { 'ARRAY' 'OF' } Qualident
=:
ModuleDeclaration := 'MODULE' Ident [ Priority ] ';'
                  { Import } [ Export ] Block
                  Ident
=:
Priority := '[' ConstExpression ']'
=:
Export := 'EXPORT' ( 'QUALIFIED' IdentList |
                    'UNQUALIFIED' IdentList |
                    IdentList ) ';'
=:
Import := 'FROM' Ident 'IMPORT' IdentList ';' |
         'IMPORT' IdentList ';'
=:
DefinitionModule := 'DEFINITION' 'MODULE' [ 'FOR' string
                                           ] Ident
                  ';' { Import } [ Export ] {
    Definition } 'END' Ident '.'
=:
Definition := 'CONST' { ConstantDeclaration ';' } |
             'TYPE' { Ident ( ';' | '=' Type Alignment
                             ';' ) } |
             'VAR' { VariableDeclaration ';' } |
             DefProcedureHeading ';'
=:
AsmStatement := 'ASM' [ 'VOLATILE' ] '(' AsmOperands
               ')'
=:
NamedOperand := '[' Ident ']'
=:
AsmOperandName := [ NamedOperand ]
=:
AsmOperands := string [ ':' AsmList [ ':' AsmList [
    ':' TrashList ] ] ]
=:
AsmList := [ AsmElement ] { ',' AsmElement }
=:
AsmElement := AsmOperandName string '(' Expression
             ')'

```

```
      =:  
TrashList := [ string ] { ',' string }  
      =:
```

## 4 PIM and ISO library definitions

This chapter contains M2F, PIM and ISO libraries.

### 4.1 Base libraries

These are the base libraries for the GNU Modula-2 compiler. These modules originally came from the M2F compiler and have been cleaned up and extended. They provide a basic interface to the underlying operating system via libc. They also include a number of libraries to allow access to compiler built-ins. Perhaps the largest difference to PIM and ISO libraries is the `DynamicString` module which declares the type `String`. The heavy use of this opaque data type results in a number of equivalent modules that can either handle `ARRAY OF CHAR` or `String`.

These modules have been extensively tested and are used throughout building the GNU Modula-2 compiler.

#### 4.1.1 gm2-libs/ARRAYOFCHAR

```

DEFINITION MODULE ARRAYOFCHAR ;

FROM FIO IMPORT File ;

(*
   Description: provides write procedures for ARRAY OF CHAR.
*)

PROCEDURE Write (f: File; str: ARRAY OF CHAR) ;
PROCEDURE WriteLn (f: File) ;

END ARRAYOFCHAR.
```

### 4.1.2 gm2-libs/ASCII

```

DEFINITION MODULE ASCII ;

EXPORT QUALIFIED
    nul, soh, stx, etx, eot, enq, ack, bel,
    bs , ht , nl , vt , np , cr , so , si ,
    dle, dc1, dc2, dc3, dc4, nak, syn, etb,
    can, em , sub, esc, fs , gs , rs , us ,
    sp , (* All the above are in order *)
    lf, ff, eof, del, tab, EOL ;

(*
    Note that lf, eof and EOL are added.
*)

CONST
    nul=000C; soh=001C; stx=002C; etx=003C;
    eot=004C; enq=005C; ack=006C; bel=007C;
    bs =010C; ht =011C; nl =012C; vt =013C;
    np =014C; cr =015C; so =016C; si =017C;
    dle=020C; dc1=021C; dc2=022C; dc3=023C;
    dc4=024C; nak=025C; syn=026C; etb=027C;
    can=030C; em =031C; sub=032C; esc=033C;
    fs =034C; gs =035C; rs =036C; us =037C;
    sp =040C; (* All the above are in order *)
    lf =nl  ; ff =np  ; eof=eot ; tab=ht  ;
    del=177C; EOL=nl  ;

END ASCII.

```

### 4.1.3 gm2-libs/Args

```
DEFINITION MODULE Args ;
```

```
EXPORT QUALIFIED GetArg, Narg ;
```

```
(*  
  GetArg - returns the nth argument from the command line.  
           The success of the operation is returned.  
*)
```

```
PROCEDURE GetArg (VAR a: ARRAY OF CHAR; n: CARDINAL) : BOOLEAN ;
```

```
(*  
  Narg - returns the number of arguments available from  
         command line.  
*)
```

```
PROCEDURE Narg () : CARDINAL ;
```

```
END Args.
```

#### 4.1.4 gm2-libs/Assertion

```
DEFINITION MODULE Assertion ;
```

```
EXPORT QUALIFIED Assert ;
```

```
(*  
  Assert - tests the boolean Condition, if it fails then HALT  
           is called.  
*)
```

```
PROCEDURE Assert (Condition: BOOLEAN) ;
```

```
END Assertion.
```

#### 4.1.5 gm2-libs/Break

```
DEFINITION MODULE Break ;
```

```
END Break.
```

### 4.1.6 gm2-libs/Builtins

```

DEFINITION MODULE Builtins ;

FROM SYSTEM IMPORT ADDRESS ;

(* Floating point intrinsic procedure functions. *)

PROCEDURE __BUILTIN__ isnanf (x: SHORTREAL) : INTEGER ;
PROCEDURE __BUILTIN__ isnan (x: REAL) : INTEGER ;
PROCEDURE __BUILTIN__ isnanl (x: LONGREAL) : INTEGER ;

PROCEDURE __BUILTIN__ isfinitef (x: SHORTREAL) : INTEGER ;
PROCEDURE __BUILTIN__ isfinite (x: REAL) : INTEGER ;
PROCEDURE __BUILTIN__ isfinitel (x: LONGREAL) : INTEGER ;

PROCEDURE __BUILTIN__ sinf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ sin (x: REAL) : REAL ;
PROCEDURE __BUILTIN__ sinl (x: LONGREAL) : LONGREAL ;

PROCEDURE __BUILTIN__ cosf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ cos (x: REAL) : REAL ;
PROCEDURE __BUILTIN__ cosl (x: LONGREAL) : LONGREAL ;

PROCEDURE __BUILTIN__ sqrtf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ sqrt (x: REAL) : REAL ;
PROCEDURE __BUILTIN__ sqrtl (x: LONGREAL) : LONGREAL ;

PROCEDURE __BUILTIN__ atan2f (x, y: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ atan2 (x, y: REAL) : REAL ;
PROCEDURE __BUILTIN__ atan2l (x, y: LONGREAL) : LONGREAL ;

PROCEDURE __BUILTIN__ fabsf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ fabs (x: REAL) : REAL ;
PROCEDURE __BUILTIN__ fabsl (x: LONGREAL) : LONGREAL ;

PROCEDURE __BUILTIN__ logf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ log (x: REAL) : REAL ;
PROCEDURE __BUILTIN__ logl (x: LONGREAL) : LONGREAL ;

PROCEDURE __BUILTIN__ expf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ exp (x: REAL) : REAL ;
PROCEDURE __BUILTIN__ expl (x: LONGREAL) : LONGREAL ;

PROCEDURE __BUILTIN__ log10f (x: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ log10 (x: REAL) : REAL ;
PROCEDURE __BUILTIN__ log10l (x: LONGREAL) : LONGREAL ;

```

```

PROCEDURE __BUILTIN__ exp10f (x: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ exp10 (x: REAL) : REAL ;
PROCEDURE __BUILTIN__ exp10l (x: LONGREAL) : LONGREAL ;

PROCEDURE __BUILTIN__ ilogbf (x: SHORTREAL) : INTEGER ;
PROCEDURE __BUILTIN__ ilogb (x: REAL) : INTEGER ;
PROCEDURE __BUILTIN__ ilogbl (x: LONGREAL) : INTEGER ;

PROCEDURE __BUILTIN__ huge_val () : REAL ;
PROCEDURE __BUILTIN__ huge_valf () : SHORTREAL ;
PROCEDURE __BUILTIN__ huge_vall () : LONGREAL ;

PROCEDURE __BUILTIN__ modf (x: REAL; VAR y: REAL) : REAL ;
PROCEDURE __BUILTIN__ modff (x: SHORTREAL;
                             VAR y: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ modfl (x: LONGREAL; VAR y: LONGREAL) : LONGREAL ;

PROCEDURE __BUILTIN__ signbit (r: REAL) : INTEGER ;
PROCEDURE __BUILTIN__ signbitf (s: SHORTREAL) : INTEGER ;
PROCEDURE __BUILTIN__ signbitl (l: LONGREAL) : INTEGER ;

PROCEDURE __BUILTIN__ nextafter (x, y: REAL) : REAL ;
PROCEDURE __BUILTIN__ nextafterf (x, y: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ nextafterl (x, y: LONGREAL) : LONGREAL ;

PROCEDURE __BUILTIN__ nexttoward (x: REAL; y: LONGREAL) : REAL ;
PROCEDURE __BUILTIN__ nexttowardf (x: SHORTREAL; y: LONGREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ nexttowardl (x, y: LONGREAL) : LONGREAL ;

PROCEDURE __BUILTIN__ scalbln (x: REAL; n: LONGINT) : REAL ;
PROCEDURE __BUILTIN__ scalblnf (x: SHORTREAL; n: LONGINT) : SHORTREAL ;
PROCEDURE __BUILTIN__ scalblnl (x: LONGREAL; n: LONGINT) : LONGREAL ;

PROCEDURE __BUILTIN__ scalbn (x: REAL; n: INTEGER) : REAL ;
PROCEDURE __BUILTIN__ scalbnf (x: SHORTREAL; n: INTEGER) : SHORTREAL ;
PROCEDURE __BUILTIN__ scalbnl (x: LONGREAL; n: INTEGER) : LONGREAL ;

PROCEDURE __BUILTIN__ isgreater (x, y: REAL) : INTEGER ;
PROCEDURE __BUILTIN__ isgreaterf (x, y: SHORTREAL) : INTEGER ;
PROCEDURE __BUILTIN__ isgreaterl (x, y: LONGREAL) : INTEGER ;

PROCEDURE __BUILTIN__ isgreaterequal (x, y: REAL) : INTEGER ;
PROCEDURE __BUILTIN__ isgreaterequalf (x, y: SHORTREAL) : INTEGER ;
PROCEDURE __BUILTIN__ isgreaterequall (x, y: LONGREAL) : INTEGER ;

PROCEDURE __BUILTIN__ isless (x, y: REAL) : INTEGER ;

```





```

PROCEDURE __BUILTIN__ memmove (s1, s2: ADDRESS;
                               nbytes: CARDINAL) : ADDRESS ;
PROCEDURE __BUILTIN__ strcat (dest, src: ADDRESS) : ADDRESS ;
PROCEDURE __BUILTIN__ strncat (dest, src: ADDRESS;
                               nbytes: CARDINAL) : ADDRESS ;
PROCEDURE __BUILTIN__ strcpy (dest, src: ADDRESS) : ADDRESS ;
PROCEDURE __BUILTIN__ strncpy (dest, src: ADDRESS;
                               nbytes: CARDINAL) : ADDRESS ;
PROCEDURE __BUILTIN__ strcmp (s1, s2: ADDRESS) : INTEGER ;
PROCEDURE __BUILTIN__ strncmp (s1, s2: ADDRESS;
                               nbytes: CARDINAL) : INTEGER ;
PROCEDURE __BUILTIN__ strlen (s: ADDRESS) : INTEGER ;
PROCEDURE __BUILTIN__ strstr (haystack, needle: ADDRESS) : ADDRESS ;
PROCEDURE __BUILTIN__ strpbrk (s, accept: ADDRESS) : ADDRESS ;
PROCEDURE __BUILTIN__ strspn (s, accept: ADDRESS) : CARDINAL ;
PROCEDURE __BUILTIN__ strcspn (s, accept: ADDRESS) : CARDINAL ;
PROCEDURE __BUILTIN__ strchr (s: ADDRESS; c: INTEGER) : ADDRESS ;
PROCEDURE __BUILTIN__ strrchr (s: ADDRESS; c: INTEGER) : ADDRESS ;

PROCEDURE __BUILTIN__ clz (value: CARDINAL) : INTEGER ;
PROCEDURE __BUILTIN__ clzll (value: LONGCARD) : INTEGER ;
PROCEDURE __BUILTIN__ ctz (value: CARDINAL) : INTEGER ;
PROCEDURE __BUILTIN__ ctzll (value: LONGCARD) : INTEGER ;

(*
  longjmp - this GCC builtin restricts the val to always 1.
*)
(* do not use these two builtins, as gcc, only really
   anticipates that the Ada front end should use them
   and it only uses them in its runtime exception handling.
   We leave them here in the hope that someday they will
   behave more like their libc counterparts. *)

PROCEDURE __BUILTIN__ longjmp (env: ADDRESS; val: INTEGER) ;
PROCEDURE __BUILTIN__ setjmp (env: ADDRESS) : INTEGER ;

(*
  frame_address - returns the address of the frame.
                  The current frame is obtained if level is 0,
                  the next level up if level is 1 etc.
*)

PROCEDURE __BUILTIN__ frame_address (level: CARDINAL) : ADDRESS ;

(*

```

```
    return_address - returns the return address of function.
                    The current function return address is
                    obtained if level is 0,
                    the next level up if level is 1 etc.
*)

PROCEDURE __BUILTIN__ return_address (level: CARDINAL) : ADDRESS ;

(*
    alloca_trace - this is a no-op which is used for internal debugging.
*)

PROCEDURE alloca_trace (returned: ADDRESS; nBytes: CARDINAL) : ADDRESS ;

END Builtins.
```

### 4.1.7 gm2-libs/CFileSysOp

```

DEFINITION MODULE CFileSysOp ;

FROM SYSTEM IMPORT ADDRESS ;

(*
  Description: provides access to filesystem operations.
               The implementation module is written in C
               and the parameters behave as their C
               counterparts.
*)

TYPE
  AccessMode = SET OF AccessStatus ;
  AccessStatus = (F_OK, R_OK, W_OK, X_OK, A_FAIL) ;

PROCEDURE Unlink (filename: ADDRESS) : INTEGER ;

(*
  Access - test access to a path or file. The behavior is
           the same as defined in access(2). Except that
           on A_FAIL is only used during the return result
           indicating the underlying C access has returned
           -1 (and errno can be checked).
*)

PROCEDURE Access (pathname: ADDRESS; mode: AccessMode) : AccessMode ;

(* Return TRUE if the caller can see the existence of the file or
   directory on the filesystem. *)

(*
  IsDir - return true if filename is a regular directory.
*)

PROCEDURE IsDir (dirname: ADDRESS) : BOOLEAN ;

(*
  IsFile - return true if filename is a regular file.
*)

```

```
PROCEDURE IsFile (filename: ADDRESS) : BOOLEAN ;

(*
  Exists - return true if pathname exists.
*)

PROCEDURE Exists (pathname: ADDRESS) : BOOLEAN ;

END CFileSysOp.
```

#### 4.1.8 gm2-libs/CHAR

```
DEFINITION MODULE CHAR ;

FROM FIO IMPORT File ;

(*
  Write a single character ch to file f.
*)

PROCEDURE Write (f: File; ch: CHAR) ;
PROCEDURE WriteLn (f: File) ;

END CHAR.
```

#### 4.1.9 gm2-libs/COROUTINES

```
DEFINITION MODULE FOR "C" COROUTINES ;

CONST
    UnassignedPriority = 0 ;

TYPE
    INTERRUPTSOURCE = CARDINAL ;
    PROTECTION = [UnassignedPriority..7] ;

END COROUTINES.
```

#### 4.1.10 gm2-libs/CmdArgs

```
DEFINITION MODULE CmdArgs ;

EXPORT QUALIFIED GetArg, Narg ;

(*
  GetArg - returns the nth argument from the command line, CmdLine
           the success of the operation is returned.
*)

PROCEDURE GetArg (CmdLine: ARRAY OF CHAR;
                  n: CARDINAL; VAR Argi: ARRAY OF CHAR) : BOOLEAN ;

(*
  Narg - returns the number of arguments available from
         command line, CmdLine.
*)

PROCEDURE Narg (CmdLine: ARRAY OF CHAR) : CARDINAL ;

END CmdArgs.
```

#### 4.1.11 gm2-libs/Debug

```
DEFINITION MODULE Debug ;

(*
  Description: provides some simple debugging routines.
*)

EXPORT QUALIFIED Halt, DebugString ;

(*
  Halt - writes a message in the format:
          Module:Function:Line:Message

          It then terminates by calling HALT.
*)

PROCEDURE Halt (Message,
               Module,
               Function: ARRAY OF CHAR ;
               LineNo  : CARDINAL) ;

(*
  DebugString - writes a string to the debugging device (Scn.Write).
               It interprets \n as carriage return, linefeed.
*)

PROCEDURE DebugString (a: ARRAY OF CHAR) ;

END Debug.
```

#### 4.1.12 gm2-libs/DynamicStrings

```

DEFINITION MODULE DynamicStrings ;

FROM SYSTEM IMPORT ADDRESS ;
EXPORT QUALIFIED String,
    InitString, KillString, Fin, InitStringCharStar,
    InitStringChar, Index, RIndex, ReverseIndex,
    Mark, Length, ConCat, ConCatChar, Assign, Dup, Add,
    Equal, EqualCharStar, EqualArray, ToUpper, ToLower,
    CopyOut, Mult, Slice, ReplaceChar,
    RemoveWhitePrefix, RemoveWhitePostfix, RemoveComment,
    char, string,
    InitStringDB, InitStringCharStarDB, InitStringCharDB,
    MultDB, DupDB, SliceDB,
    PushAllocation, PopAllocation, PopAllocationExemption ;

TYPE
    String ;

(*
    InitString - creates and returns a String type object.
                  Initial contents are, a.
*)

PROCEDURE InitString (a: ARRAY OF CHAR) : String ;

(*
    KillString - frees String, s, and its contents.
                  NIL is returned.
*)

PROCEDURE KillString (s: String) : String ;

(*
    Fin - finishes with a string, it calls KillString with, s.
          The purpose of the procedure is to provide a short cut
          to calling KillString and then testing the return result.
*)

PROCEDURE Fin (s: String) ;

(*

```

```
    InitStringCharStar - initializes and returns a String to contain
                        the C string.
*)

PROCEDURE InitStringCharStar (a: ADDRESS) : String ;

(*
    InitStringChar - initializes and returns a String to contain the
                    single character, ch.
*)

PROCEDURE InitStringChar (ch: CHAR) : String ;

(*
    Mark - marks String, s, ready for garbage collection.
*)

PROCEDURE Mark (s: String) : String ;

(*
    Length - returns the length of the String, s.
*)

PROCEDURE Length (s: String) : CARDINAL ;

(*
    ConCat - returns String, a, after the contents of, b,
            have been appended.
*)

PROCEDURE ConCat (a, b: String) : String ;

(*
    ConCatChar - returns String, a, after character, ch,
                has been appended.
*)

PROCEDURE ConCatChar (a: String; ch: CHAR) : String ;

(*
    Assign - assigns the contents of, b, into, a.
```

```
String, a, is returned.
*)

PROCEDURE Assign (a, b: String) : String ;

(*
  ReplaceChar - returns string s after it has changed all
                occurrences of from to to.
*)

PROCEDURE ReplaceChar (s: String; from, to: CHAR) : String ;

(*
  Dup - duplicate a String, s, returning the copy of s.
*)

PROCEDURE Dup (s: String) : String ;

(*
  Add - returns a new String which contains the contents of a and b.
*)

PROCEDURE Add (a, b: String) : String ;

(*
  Equal - returns TRUE if String, a, and, b, are equal.
*)

PROCEDURE Equal (a, b: String) : BOOLEAN ;

(*
  EqualCharStar - returns TRUE if contents of String, s, is
                  the same as the string, a.
*)

PROCEDURE EqualCharStar (s: String; a: ADDRESS) : BOOLEAN ;

(*
  EqualArray - returns TRUE if contents of String, s, is the
               same as the string, a.
*)
```

```
PROCEDURE EqualArray (s: String; a: ARRAY OF CHAR) : BOOLEAN ;
```

```
(*
  Mult - returns a new string which is n concatenations of String, s.
         If n<=0 then an empty string is returned.
*)
```

```
PROCEDURE Mult (s: String; n: CARDINAL) : String ;
```

```
(*
  Slice - returns a new string which contains the elements
          low..high-1

          strings start at element 0
          Slice(s, 0, 2) will return elements 0, 1 but not 2
          Slice(s, 1, 3) will return elements 1, 2 but not 3
          Slice(s, 2, 0) will return elements 2..max
          Slice(s, 3, -1) will return elements 3..max-1
          Slice(s, 4, -2) will return elements 4..max-2
*)
```

```
PROCEDURE Slice (s: String; low, high: INTEGER) : String ;
```

```
(*
  Index - returns the indice of the first occurrence of, ch, in
          String, s. -1 is returned if, ch, does not exist.
          The search starts at position, o.
*)
```

```
PROCEDURE Index (s: String; ch: CHAR; o: CARDINAL) : INTEGER ;
```

```
(*
  RIndex - returns the indice of the last occurrence of, ch,
           in String, s. The search starts at position, o.
           -1 is returned if ch is not found. The search
           is performed left to right.
*)
```

```
PROCEDURE RIndex (s: String; ch: CHAR; o: CARDINAL) : INTEGER ;
```

```
(*
```

ReverseIndex - returns the indice of the last occurrence of ch  
 in String s. The search starts at position o  
 and searches from right to left. The start position  
 may be indexed negatively from the right (-1 is the  
 last index).  
 The return value if ch is found will always be positive.■  
 -1 is returned if ch is not found.

\*)

PROCEDURE ReverseIndex (s: String; ch: CHAR; o: INTEGER) : INTEGER ;

(\*

RemoveComment - assuming that, comment, is a comment delimiter  
 which indicates anything to its right is a comment  
 then strip off the comment and also any white space  
 on the remaining right hand side.  
 It leaves any white space on the left hand side  
 alone.

\*)

PROCEDURE RemoveComment (s: String; comment: CHAR) : String ;

(\*

RemoveWhitePrefix - removes any leading white space from String, s.  
 A new string is returned.

\*)

PROCEDURE RemoveWhitePrefix (s: String) : String ;

(\*

RemoveWhitePostfix - removes any leading white space from String, s.  
 A new string is returned.

\*)

PROCEDURE RemoveWhitePostfix (s: String) : String ;

(\*

ToUpper - returns string, s, after it has had its lower case  
 characters replaced by upper case characters.  
 The string, s, is not duplicated.

\*)

PROCEDURE ToUpper (s: String) : String ;

```

(*)
    ToLower - returns string, s, after it has had its upper case
              characters replaced by lower case characters.
              The string, s, is not duplicated.
*)

PROCEDURE ToLower (s: String) : String ;

(*)
    CopyOut - copies string, s, to a.
*)

PROCEDURE CopyOut (VAR a: ARRAY OF CHAR; s: String) ;

(*)
    char - returns the character, ch, at position, i, in String, s.
           As Slice the index can be negative so:

           char(s, 0) will return the first character
           char(s, 1) will return the second character
           char(s, -1) will return the last character
           char(s, -2) will return the penultimate character

           a nul character is returned if the index is out of range.
*)

PROCEDURE char (s: String; i: INTEGER) : CHAR ;

(*)
    string - returns the C style char * of String, s.
*)

PROCEDURE string (s: String) : ADDRESS ;

(*)
    to easily debug an application using this library one could use
    use the following macro processing defines:

    #define InitString(X) InitStringDB(X, __FILE__, __LINE__)
    #define InitStringCharStar(X) InitStringCharStarDB(X, \
        __FILE__, __LINE__)

```

```

#define InitStringChar(X) InitStringCharDB(X, __FILE__, __LINE__)
#define Mult(X,Y) MultDB(X, Y, __FILE__, __LINE__)
#define Dup(X) DupDB(X, __FILE__, __LINE__)
#define Slice(X,Y,Z) SliceDB(X, Y, Z, __FILE__, __LINE__)

    and then invoke gm2 with the -fcpp flag.
*)

(*
    InitStringDB - the debug version of InitString.
*)

PROCEDURE InitStringDB (a: ARRAY OF CHAR;
                        file: ARRAY OF CHAR; line: CARDINAL) : String ;

(*
    InitStringCharStarDB - the debug version of InitStringCharStar.
*)

PROCEDURE InitStringCharStarDB (a: ADDRESS;
                                file: ARRAY OF CHAR;
                                line: CARDINAL) : String ;

(*
    InitStringCharDB - the debug version of InitStringChar.
*)

PROCEDURE InitStringCharDB (ch: CHAR;
                            file: ARRAY OF CHAR;
                            line: CARDINAL) : String ;

(*
    MultDB - the debug version of MultDB.
*)

PROCEDURE MultDB (s: String; n: CARDINAL;
                  file: ARRAY OF CHAR; line: CARDINAL) : String ;

(*
    DupDB - the debug version of Dup.
*)

```

```

PROCEDURE DupDB (s: String;
                 file: ARRAY OF CHAR; line: CARDINAL) : String ;

(*
  SliceDB - debug version of Slice.
*)

PROCEDURE SliceDB (s: String; low, high: INTEGER;
                  file: ARRAY OF CHAR; line: CARDINAL) : String ;

(*
  PushAllocation - pushes the current allocation/deallocation lists.
*)

PROCEDURE PushAllocation ;

(*
  PopAllocation - test to see that all strings are deallocated since
                  the last push. Then it pops to the previous
                  allocation/deallocation lists.

                  If halt is true then the application terminates
                  with an exit code of 1.
*)

PROCEDURE PopAllocation (halt: BOOLEAN) ;

(*
  PopAllocationExemption - test to see that all strings are
                          deallocated, except string e since
                          the last push.
                          Post-condition: it pops to the previous
                          allocation/deallocation lists.

                          If halt is true then the application
                          terminates with an exit code of 1.

                          The string, e, is returned unmodified,
*)

PROCEDURE PopAllocationExemption (halt: BOOLEAN; e: String) : String ;

END DynamicStrings.

```

#### 4.1.13 gm2-libs/Environment

```
DEFINITION MODULE Environment ;

EXPORT QUALIFIED GetEnvironment, PutEnvironment ;

(*
  GetEnvironment - gets the environment variable Env and places
                  a copy of its value into string, dest.
                  It returns TRUE if the string Env was found in
                  the processes environment.
*)

PROCEDURE GetEnvironment (Env: ARRAY OF CHAR;
                        VAR dest: ARRAY OF CHAR) : BOOLEAN ;

(*
  PutEnvironment - change or add an environment variable definition
                  EnvDef.
                  TRUE is returned if the environment variable was
                  set or changed successfully.
*)

PROCEDURE PutEnvironment (EnvDef: ARRAY OF CHAR) : BOOLEAN ;

END Environment.
```

## 4.1.14 gm2-libs/FIO

```

DEFINITION MODULE FIO ;

(* Provides a simple buffered file input/output library. *)

FROM SYSTEM IMPORT ADDRESS, BYTE ;

EXPORT QUALIFIED (* types *)
    File,
    (* procedures *)
    OpenToRead, OpenToWrite, OpenForRandom, Close,
    EOF, EOLN, WasEOLN, IsNoError, Exists, IsActive,
    exists, openToRead, openToWrite, openForRandom,
    SetPositionFromBeginning,
    SetPositionFromEnd,
    FindPosition,
    ReadChar, ReadString,
    WriteChar, WriteString, WriteLine,
    WriteCardinal, ReadCardinal,
    UnReadChar,
    WriteNBytes, ReadNBytes,
    FlushBuffer,
    GetUnixFileDescriptor,
    GetFileName, getFileName, getFileNameLength,
    FlushOutErr,
    (* variables *)
    StdIn, StdOut, StdErr ;

TYPE
    File = CARDINAL ;

(* the following variables are initialized to their UNIX equivalents *)
VAR
    StdIn, StdOut, StdErr: File ;

(*
    IsNoError - returns a TRUE if no error has occurred on file, f.
*)

PROCEDURE IsNoError (f: File) : BOOLEAN ;

(*

```

```
    IsActive - returns TRUE if the file, f, is still active.
*)

PROCEDURE IsActive (f: File) : BOOLEAN ;

(*
    Exists - returns TRUE if a file named, fname exists for reading.
*)

PROCEDURE Exists (fname: ARRAY OF CHAR) : BOOLEAN ;

(*
    OpenToRead - attempts to open a file, fname, for reading and
                  it returns this file.
                  The success of this operation can be checked by
                  calling IsNoError.
*)

PROCEDURE OpenToRead (fname: ARRAY OF CHAR) : File ;

(*
    OpenToWrite - attempts to open a file, fname, for write and
                  it returns this file.
                  The success of this operation can be checked by
                  calling IsNoError.
*)

PROCEDURE OpenToWrite (fname: ARRAY OF CHAR) : File ;

(*
    OpenForRandom - attempts to open a file, fname, for random access
                    read or write and it returns this file.
                    The success of this operation can be checked by
                    calling IsNoError.
                    towrite, determines whether the file should be
                    opened for writing or reading.
                    newfile, determines whether a file should be
                    created if towrite is TRUE or whether the
                    previous file should be left alone,
                    allowing this descriptor to seek
                    and modify an existing file.
*)
```

```

PROCEDURE OpenForRandom (fname: ARRAY OF CHAR;
                        towrite, newfile: BOOLEAN) : File ;

(*
  Close - close a file which has been previously opened using:
          OpenToRead, OpenToWrite, OpenForRandom.
          It is correct to close a file which has an error status.
*)

PROCEDURE Close (f: File) ;

(* the following functions are functionally equivalent to the above
   except they allow C style names.
*)

PROCEDURE exists      (fname: ADDRESS; flength: CARDINAL) : BOOLEAN ;
PROCEDURE openToRead  (fname: ADDRESS; flength: CARDINAL) : File ;
PROCEDURE openToWrite (fname: ADDRESS; flength: CARDINAL) : File ;
PROCEDURE openForRandom (fname: ADDRESS; flength: CARDINAL;
                        towrite, newfile: BOOLEAN) : File ;

(*
  FlushBuffer - flush contents of the FIO file, f, to libc.
*)

PROCEDURE FlushBuffer (f: File) ;

(*
  ReadNBytes - reads nBytes of a file into memory area, dest, returning
               the number of bytes actually read.
               This function will consume from the buffer and then
               perform direct libc reads. It is ideal for large reads.
*)

PROCEDURE ReadNBytes (f: File; nBytes: CARDINAL;
                     dest: ADDRESS) : CARDINAL ;

(*
  ReadAny - reads HIGH (a) + 1 bytes into, a. All input
            is fully buffered, unlike ReadNBytes and thus is more
            suited to small reads.
*)

```

```
PROCEDURE ReadAny (f: File; VAR a: ARRAY OF BYTE) ;
```

```
(*
  WriteNBytes - writes nBytes from memory area src to a file
                returning the number of bytes actually written.
                This function will flush the buffer and then
                write the nBytes using a direct write from libc.
                It is ideal for large writes.
*)
```

```
PROCEDURE WriteNBytes (f: File; nBytes: CARDINAL;
                      src: ADDRESS) : CARDINAL ;
```

```
(*
  WriteAny - writes HIGH (a) + 1 bytes onto, file, f. All output
             is fully buffered, unlike WriteNBytes and thus is more
             suited to small writes.
*)
```

```
PROCEDURE WriteAny (f: File; VAR a: ARRAY OF BYTE) ;
```

```
(*
  WriteChar - writes a single character to file, f.
*)
```

```
PROCEDURE WriteChar (f: File; ch: CHAR) ;
```

```
(*
  EOF - tests to see whether a file, f, has reached end of file.
*)
```

```
PROCEDURE EOF (f: File) : BOOLEAN ;
```

```
(*
  EOLN - tests to see whether a file, f, is about to read a newline.
         It does NOT consume the newline. It reads the next character
         and then immediately unreads the character.
*)
```

```
PROCEDURE EOLN (f: File) : BOOLEAN ;
```

```
(*
  WasEOLN - tests to see whether a file, f, has just read a newline
            character.
*)
```

```
PROCEDURE WasEOLN (f: File) : BOOLEAN ;
```

```
(*
  ReadChar - returns a character read from file, f.
             Sensible to check with IsNoError or EOF after calling
             this function.
*)
```

```
PROCEDURE ReadChar (f: File) : CHAR ;
```

```
(*
  UnReadChar - replaces a character, ch, back into file, f.
               This character must have been read by ReadChar
               and it does not allow successive calls. It may
               only be called if the previous read was successful,
               end of file or end of line seen.
*)
```

```
PROCEDURE UnReadChar (f: File ; ch: CHAR) ;
```

```
(*
  WriteLine - writes out a linefeed to file, f.
*)
```

```
PROCEDURE WriteLine (f: File) ;
```

```
(*
  WriteString - writes a string to file, f.
*)
```

```
PROCEDURE WriteString (f: File; a: ARRAY OF CHAR) ;
```

```
(*
  ReadString - reads a string from file, f, into string, a.
               It terminates the string if HIGH is reached or
               if a newline is seen or an error occurs.
*)
```

```
*)

PROCEDURE ReadString (f: File; VAR a: ARRAY OF CHAR) ;

(*
  WriteCardinal - writes a CARDINAL to file, f.
                  It writes the binary image of the CARDINAL.
                  to file, f.
*)

PROCEDURE WriteCardinal (f: File; c: CARDINAL) ;

(*
  ReadCardinal - reads a CARDINAL from file, f.
                 It reads a bit image of a CARDINAL
                 from file, f.
*)

PROCEDURE ReadCardinal (f: File) : CARDINAL ;

(*
  GetUnixFileDescriptor - returns the UNIX file descriptor of a file.
                         Useful when combining FIO.mod with select
                         (in Selective.def - but note the comments in
                         Selective about using read/write primitives)
*)

PROCEDURE GetUnixFileDescriptor (f: File) : INTEGER ;

(*
  SetPositionFromBeginning - sets the position from the beginning
                           of the file.
*)

PROCEDURE SetPositionFromBeginning (f: File; pos: LONGINT) ;

(*
  SetPositionFromEnd - sets the position from the end of the file.
*)

PROCEDURE SetPositionFromEnd (f: File; pos: LONGINT) ;
```

```
(*
  FindPosition - returns the current absolute position in file, f.
*)

PROCEDURE FindPosition (f: File) : LONGINT ;

(*
  GetFileName - assigns, a, with the filename associated with, f.
*)

PROCEDURE GetFileName (f: File; VAR a: ARRAY OF CHAR) ;

(*
  getFileName - returns the address of the filename associated with, f.
*)

PROCEDURE getFileName (f: File) : ADDRESS ;

(*
  getFileNameLength - returns the number of characters associated with
                      filename, f.
*)

PROCEDURE getFileNameLength (f: File) : CARDINAL ;

(*
  FlushOutErr - flushes, StdOut, and, StdErr.
*)

PROCEDURE FlushOutErr ;

END FIO.
```

#### 4.1.15 gm2-libs/FileSysOp

```
DEFINITION MODULE FileSysOp ;

FROM CFileSysOp IMPORT AccessMode ;

(*
  Description: provides access to filesystem operations using
              Modula-2 base types.
*)

PROCEDURE Exists (filename: ARRAY OF CHAR) : BOOLEAN ;
PROCEDURE IsDir (dirname: ARRAY OF CHAR) : BOOLEAN ;
PROCEDURE IsFile (filename: ARRAY OF CHAR) : BOOLEAN ;
PROCEDURE Unlink (filename: ARRAY OF CHAR) : BOOLEAN ;
PROCEDURE Access (pathname: ARRAY OF CHAR; mode: AccessMode) : AccessMode ;

END FileSysOp.
```

#### 4.1.16 gm2-libs/FormatStrings

```
DEFINITION MODULE FormatStrings ;

FROM SYSTEM IMPORT BYTE ;
FROM DynamicStrings IMPORT String ;
EXPORT QUALIFIED Sprintf0, Sprintf1, Sprintf2, Sprintf3, Sprintf4,
                  HandleEscape ;

(*
  Sprintf0 - returns a String containing, fmt, after it has had its
             escape sequences translated.
*)

PROCEDURE Sprintf0 (fmt: String) : String ;

(*
  Sprintf1 - returns a String containing, fmt, together with
             encapsulated entity, w. It only formats the
             first %s or %d with n.
*)

PROCEDURE Sprintf1 (fmt: String; w: ARRAY OF BYTE) : String ;

(*
  Sprintf2 - returns a string, fmt, which has been formatted.
*)

PROCEDURE Sprintf2 (fmt: String; w1, w2: ARRAY OF BYTE) : String ;

(*
  Sprintf3 - returns a string, fmt, which has been formatted.
*)

PROCEDURE Sprintf3 (fmt: String; w1, w2, w3: ARRAY OF BYTE) : String ;

(*
  Sprintf4 - returns a string, fmt, which has been formatted.
*)

PROCEDURE Sprintf4 (fmt: String;
                   w1, w2, w3, w4: ARRAY OF BYTE) : String ;
```

```
(*  
  HandleEscape - translates \a, \b, \e, \f, \n, \r, \x[hex] \[octal]  
                  into their respective ascii codes. It also converts  
                  \[any] into a single [any] character.  
*)  
  
PROCEDURE HandleEscape (s: String) : String ;  
  
END FormatStrings.
```

## 4.1.17 gm2-libs/FpuIO

```

DEFINITION MODULE FpuIO ;

EXPORT QUALIFIED ReadReal, WriteReal, StrToReal, RealToStr,
                  ReadLongReal, WriteLongReal, StrToLongReal,
                  LongRealToStr,
                  ReadLongInt, WriteLongInt, StrToLongInt,
                  LongIntToStr ;

PROCEDURE ReadReal (VAR x: REAL) ;
PROCEDURE WriteReal (x: REAL; TotalWidth, FractionWidth: CARDINAL) ;
PROCEDURE StrToReal (a: ARRAY OF CHAR ; VAR x: REAL) ;
PROCEDURE RealToStr (x: REAL; TotalWidth, FractionWidth: CARDINAL;
                    VAR a: ARRAY OF CHAR) ;

PROCEDURE ReadLongReal (VAR x: LONGREAL) ;
PROCEDURE WriteLongReal (x: LONGREAL;
                        TotalWidth, FractionWidth: CARDINAL) ;
PROCEDURE StrToLongReal (a: ARRAY OF CHAR ; VAR x: LONGREAL) ;
PROCEDURE LongRealToStr (x: LONGREAL;
                        TotalWidth, FractionWidth: CARDINAL;
                        VAR a: ARRAY OF CHAR) ;

PROCEDURE ReadLongInt (VAR x: LONGINT) ;
PROCEDURE WriteLongInt (x: LONGINT; n: CARDINAL) ;
PROCEDURE StrToLongInt (a: ARRAY OF CHAR ; VAR x: LONGINT) ;
PROCEDURE LongIntToStr (x: LONGINT; n: CARDINAL; VAR a: ARRAY OF CHAR) ;

END FpuIO.

```

#### 4.1.18 gm2-libs/GetOpt

```

DEFINITION MODULE GetOpt ;

FROM SYSTEM IMPORT ADDRESS ;
FROM DynamicStrings IMPORT String ;

CONST
    no_argument = 0 ;
    required_argument = 1 ;
    optional_argument = 2 ;

TYPE
    LongOptions ;
    PtrToInteger = POINTER TO INTEGER ;

(*
    GetOpt - call C getopt and fill in the parameters:
             optarg, optind, opterr and optopt.
*)

PROCEDURE GetOpt (argc: INTEGER; argv: ADDRESS; optstring: String;
                 VAR optarg: String;
                 VAR optind, opterr, optopt: INTEGER) : CHAR ;

(*
    InitLongOptions - creates and returns a LongOptions empty array.
*)

PROCEDURE InitLongOptions () : LongOptions ;

(*
    AddLongOption - appends long option {name, has_arg, flag, val} to the
                   array of options and new long options array is
                   returned.
                   The old array, lo, should no longer be used.

    (from man 3 getopt)
    The meanings of the different fields are:

    name    is the name of the long option.

    has_arg
    is: no_argument (or 0) if the option does not take an
        argument; required_argument (or 1) if the option

```

requires an argument; or `optional_argument` (or 2) if the option takes an optional argument.

`flag` specifies how results are returned for a long option. If `flag` is `NULL`, then `getopt_long()` returns `val`. (For example, the calling program may set `val` to the equivalent short option character). Otherwise, `getopt_long()` returns 0, and `flag` points to a variable which is set to `val` if the option is found, but left unchanged if the option is not found.

`val` is the value to return, or to load into the variable pointed to by `flag`.

The last element of the array must be filled with zeros.

\*)

```
PROCEDURE AddLongOption (lo: LongOptions; index: CARDINAL;
                        name: String; has_arg: INTEGER;
                        VAR flag: INTEGER; val: INTEGER) : LongOptions ;
```

(\*

`KillLongOptions` - returns `NIL` and also frees up memory associated with, `lo`.

\*)

```
PROCEDURE KillLongOptions (lo: LongOptions) : LongOptions ;
```

(\*

`GetOptLong` - works like `GetOpt` but will accept long options (using two dashes). If the program only accepts long options then `optstring` should be an empty string, not `NIL`.

\*)

```
PROCEDURE GetOptLong (argc: INTEGER; argv: ADDRESS;
                    optstring: String; longopts: LongOptions;
                    VAR longindex: INTEGER) : INTEGER ;
```

(\*

`GetOptLongOnly` - works like `GetOptLong` except that a single dash can be used for a long option.

\*)

```
PROCEDURE GetOptLongOnly (argc: INTEGER; argv: ADDRESS;
```

```
optstring: String; longopts: LongOptions;  
VAR longindex: INTEGER) : INTEGER ;
```

```
END GetOpt.
```

#### 4.1.19 gm2-libs/IO

```
DEFINITION MODULE IO ;
```

```
(*
  Description: provides Read, Write, Errors procedures that map onto UNIX
               file descriptors 0, 1 and 2. This is achieved by using
               FIO if we are in buffered mode and using libc.write
               if not.
*)
```

```
EXPORT QUALIFIED Read, Write, Error,
                  UnBufferedMode, BufferedMode,
                  EchoOn, EchoOff ;
```

```
PROCEDURE Read (VAR ch: CHAR) ;
PROCEDURE Write (ch: CHAR) ;
PROCEDURE Error (ch: CHAR) ;
```

```
(*
  UnBufferedMode - places file descriptor, fd, into an unbuffered mode.
*)
```

```
PROCEDURE UnBufferedMode (fd: INTEGER; input: BOOLEAN) ;
```

```
(*
  BufferedMode - places file descriptor, fd, into a buffered mode.
*)
```

```
PROCEDURE BufferedMode (fd: INTEGER; input: BOOLEAN) ;
```

```
(*
  EchoOn - turns on echoing for file descriptor, fd. This
           only really makes sence for a file descriptor opened
           for terminal input or maybe some specific file descriptor
           which is attached to a particular piece of hardware.
*)
```

```
PROCEDURE EchoOn (fd: INTEGER; input: BOOLEAN) ;
```

```
(*
  EchoOff - turns off echoing for file descriptor, fd. This
```

only really makes sence for a file descriptor opened  
for terminal input or maybe some specific file descriptor  
which is attached to a particular piece of hardware.

\*)

PROCEDURE EchoOff (fd: INTEGER; input: BOOLEAN) ;

END IO.

#### 4.1.20 gm2-libs/Indexing

```

DEFINITION MODULE Indexing ;

FROM SYSTEM IMPORT ADDRESS ;

TYPE
  Index ;
  IndexProcedure = PROCEDURE (ADDRESS) ;

(*
  InitIndexTuned - creates a dynamic array with low indice.
                  minsize is the initial number of elements the
                  array is allocated and growfactor determines how
                  it will be resized once it becomes full.
*)

PROCEDURE InitIndexTuned (low, minsize, growfactor: CARDINAL) : Index ;

(*
  InitIndex - creates and returns an Index.
*)

PROCEDURE InitIndex (low: CARDINAL) : Index ;

(*
  KillIndex - returns Index to free storage.
*)

PROCEDURE KillIndex (i: Index) : Index ;

(*
  DebugIndex - turns on debugging within an index.
*)

PROCEDURE DebugIndex (i: Index) : Index ;

(*
  InBounds - returns TRUE if indice, n, is within the bounds
             of the dynamic array.
*)

```

```
PROCEDURE InBounds (i: Index; n: CARDINAL) : BOOLEAN ;

(*
  HighIndice - returns the last legally accessible indice of this array.■
*)

PROCEDURE HighIndice (i: Index) : CARDINAL ;

(*
  LowIndice - returns the first legally accessible indice of this array.■
*)

PROCEDURE LowIndice (i: Index) : CARDINAL ;

(*
  PutIndice - places, a, into the dynamic array at position i[n]
*)

PROCEDURE PutIndice (i: Index; n: CARDINAL; a: ADDRESS) ;

(*
  GetIndice - retrieves, element i[n] from the dynamic array.
*)

PROCEDURE GetIndice (i: Index; n: CARDINAL) : ADDRESS ;

(*
  IsIndiceInIndex - returns TRUE if, a, is in the index, i.
*)

PROCEDURE IsIndiceInIndex (i: Index; a: ADDRESS) : BOOLEAN ;

(*
  RemoveIndiceFromIndex - removes, a, from Index, i.
*)

PROCEDURE RemoveIndiceFromIndex (i: Index; a: ADDRESS) ;

(*
```

```

    DeleteIndice - delete i[j] from the array.
*)

PROCEDURE DeleteIndice (i: Index; j: CARDINAL) ;

(*
    IncludeIndiceIntoIndex - if the indice is not in the index, then
                           add it at the end.
*)

PROCEDURE IncludeIndiceIntoIndex (i: Index; a: ADDRESS) ;

(*
    ForeachIndiceInIndexDo - for each j indice of i, call procedure p(i[j])
*)

PROCEDURE ForeachIndiceInIndexDo (i: Index; p: IndexProcedure) ;

(*
    IsEmpty - return TRUE if the array has no entries it.
*)

PROCEDURE IsEmpty (i: Index) : BOOLEAN ;

(*
    FindIndice - returns the indice containing a.
                It returns zero if a is not found in array i.
*)

PROCEDURE FindIndice (i: Index; a: ADDRESS) : CARDINAL ;

END Indexing.
```

#### 4.1.21 gm2-libs/LMathLib0

```
DEFINITION MODULE LMathLib0 ;

CONST
  pi    = 3.1415926535897932384626433832795028841972;
  exp1  = 2.7182818284590452353602874713526624977572;

PROCEDURE __BUILTIN__ sqrt (x: LONGREAL) : LONGREAL ;
PROCEDURE exp (x: LONGREAL) : LONGREAL ;
PROCEDURE ln (x: LONGREAL) : LONGREAL ;
PROCEDURE __BUILTIN__ sin (x: LONGREAL) : LONGREAL ;
PROCEDURE __BUILTIN__ cos (x: LONGREAL) : LONGREAL ;
PROCEDURE tan (x: LONGREAL) : LONGREAL ;
PROCEDURE arctan (x: LONGREAL) : LONGREAL ;
PROCEDURE entier (x: LONGREAL) : INTEGER ;

END LMathLib0.
```

#### 4.1.22 gm2-libs/LegacyReal

```
DEFINITION MODULE LegacyReal ;
```

```
TYPE
```

```
  REAL = SHORTREAL ;
```

```
END LegacyReal.
```



```
PROCEDURE InstallTerminationProcedure (p: PROC) : BOOLEAN ;

(*
  ExecuteInitialProcedures - executes the initial procedures installed
                           by InstallInitialProcedure.
*)

PROCEDURE ExecuteInitialProcedures ;

(*
  InstallInitialProcedure - installs a procedure to be executed just
                           before the BEGIN code section of the main
                           program module.
*)

PROCEDURE InstallInitialProcedure (p: PROC) : BOOLEAN ;

(*
  ExecuteTerminationProcedures - calls each installed termination procedure
                               in reverse order.
*)

PROCEDURE ExecuteTerminationProcedures ;

END M2Dependent.
```

## 4.1.24 gm2-libs/M2EXCEPTION

```
DEFINITION MODULE M2EXCEPTION;
```

```
(* This enumerated list of exceptions must match the exceptions in gm2-libs-iso to
   allow mixed module dialect projects. *)
```

```
TYPE
```

```
  M2Exceptions =
```

```
    (indexException,      rangeException,      caseSelectException,  invalidLocation
     functionException,   wholeValueException, wholeDivException,   realValueExcept
     realDivException,   complexValueException, complexDivException, protException,
     sysException,       coException,          exException
    );
```

```
(* If the program or coroutine is in the exception state then return the enumeration
   value representing the exception cause. If it is not in the exception state then
   raises and exception (exException). *)
```

```
PROCEDURE M2Exception () : M2Exceptions;
```

```
(* Returns TRUE if the program or coroutine is in the exception state.
   Returns FALSE if the program or coroutine is not in the exception state. *)
```

```
PROCEDURE IsM2Exception () : BOOLEAN;
```

```
END M2EXCEPTION.
```



```
PROCEDURE InstallTerminationProcedure (p: PROC) : BOOLEAN ;

(*
  ExecuteInitialProcedures - executes the initial procedures installed
                           by InstallInitialProcedure.
*)

PROCEDURE ExecuteInitialProcedures ;

(*
  InstallInitialProcedure - installs a procedure to be executed just
                           before the BEGIN code section of the main
                           program module.
*)

PROCEDURE InstallInitialProcedure (p: PROC) : BOOLEAN ;

(*
  ExecuteTerminationProcedures - calls each installed termination procedure
                               in reverse order.
*)

PROCEDURE ExecuteTerminationProcedures ;

(*
  Terminate - provides compatibility for pim. It call exit with
              the exitcode provided in a prior call to ExitOnHalt
              (or zero if ExitOnHalt was never called). It does
              not call ExecuteTerminationProcedures.
*)

PROCEDURE Terminate <* noreturn *> ;

(*
  HALT - terminate the current program. The procedure Terminate
         is called before the program is stopped. The parameter
         exitcode is optional. If the parameter is not supplied
         HALT will call libc 'abort', otherwise it will exit with
         the code supplied. Supplying a parameter to HALT has the
         same effect as calling ExitOnHalt with the same code and
         then calling HALT with no parameter.
*)
```

```

PROCEDURE HALT ([exitcode: INTEGER = -1]) <* noreturn *> ;

(*
  Halt - provides a more user friendly version of HALT, which takes
         four parameters to aid debugging.  It writes an error message
         to stderr and calls exit (1).
*)

PROCEDURE Halt (description, filename, function: ARRAY OF CHAR;
               line: CARDINAL) <* noreturn *> ;

(*
  HaltC - provides a more user friendly version of HALT, which takes
          four parameters to aid debugging.  It writes an error message
          to stderr and calls exit (1).
*)

PROCEDURE HaltC (description, filename, function: ADDRESS;
                line: CARDINAL) <* noreturn *> ;

(*
  ExitOnHalt - if HALT is executed then call exit with the exit code, e.
*)

PROCEDURE ExitOnHalt (e: INTEGER) ;

(*
  ErrorMessage - emits an error message to stderr and then calls exit (1).
*)

PROCEDURE ErrorMessage (message: ARRAY OF CHAR;
                       filename: ARRAY OF CHAR;
                       line: CARDINAL;
                       function: ARRAY OF CHAR) <* noreturn *> ;

(*
  Length - returns the length of a string, a. This is called whenever
          the user calls LENGTH and the parameter cannot be calculated
          at compile time.
*)

```

```
PROCEDURE Length (a: ARRAY OF CHAR) : CARDINAL ;
```

```
(*
```

```
  The following are the runtime exception handler routines.
```

```
*)
```

```
PROCEDURE AssignmentException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE ReturnException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE IncException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE DecException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE InclException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE ExclException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE ShiftException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE RotateException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE StaticArraySubscriptException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE DynamicArraySubscriptException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE ForLoopBeginException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE ForLoopToException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE ForLoopEndException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE PointerNilException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE NoReturnException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE CaseException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE WholeNonPosDivException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE WholeNonPosModException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE WholeZeroDivException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE WholeZeroRemException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE WholeValueException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE RealValueException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE ParameterException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
PROCEDURE NoException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS;
```

```
END M2RTS.
```

#### 4.1.26 gm2-libs/MathLib0

```
DEFINITION MODULE MathLib0 ;

CONST
  pi    = 3.1415926535897932384626433832795028841972;
  exp1  = 2.7182818284590452353602874713526624977572;

PROCEDURE __BUILTIN__ sqrt (x: REAL) : REAL ;
PROCEDURE exp (x: REAL) : REAL ;
PROCEDURE ln (x: REAL) : REAL ;
PROCEDURE __BUILTIN__ sin (x: REAL) : REAL ;
PROCEDURE __BUILTIN__ cos (x: REAL) : REAL ;
PROCEDURE tan (x: REAL) : REAL ;
PROCEDURE arctan (x: REAL) : REAL ;
PROCEDURE entier (x: REAL) : INTEGER ;

END MathLib0.
```

#### 4.1.27 gm2-libs/MemUtils

```
DEFINITION MODULE MemUtils ;

FROM SYSTEM IMPORT ADDRESS ;
EXPORT QUALIFIED MemCopy, MemZero ;

(*
  MemCopy - copys a region of memory to the required destination.
*)

PROCEDURE MemCopy (from: ADDRESS; length: CARDINAL; to: ADDRESS) ;

(*
  MemZero - sets a region of memory: a..a+length to zero.
*)

PROCEDURE MemZero (a: ADDRESS; length: CARDINAL) ;

END MemUtils.
```

#### 4.1.28 gm2-libs/NumberIO

```

DEFINITION MODULE NumberIO ;

EXPORT QUALIFIED ReadCard, WriteCard, ReadHex, WriteHex, ReadInt, WriteInt,
    CardToStr, StrToCard, StrToHex, HexToStr, StrToInt, IntToStr,
    ReadOct, WriteOct, OctToStr, StrToOct,
    ReadBin, WriteBin, BinToStr, StrToBin,
    StrToBinInt, StrToHexInt, StrToOctInt ;

PROCEDURE ReadCard (VAR x: CARDINAL) ;

PROCEDURE WriteCard (x, n: CARDINAL) ;

PROCEDURE ReadHex (VAR x: CARDINAL) ;

PROCEDURE WriteHex (x, n: CARDINAL) ;

PROCEDURE ReadInt (VAR x: INTEGER) ;

PROCEDURE WriteInt (x: INTEGER ; n: CARDINAL) ;

PROCEDURE CardToStr (x, n: CARDINAL ; VAR a: ARRAY OF CHAR) ;

PROCEDURE StrToCard (a: ARRAY OF CHAR ; VAR x: CARDINAL) ;

PROCEDURE HexToStr (x, n: CARDINAL ; VAR a: ARRAY OF CHAR) ;

PROCEDURE StrToHex (a: ARRAY OF CHAR ; VAR x: CARDINAL) ;

PROCEDURE IntToStr (x: INTEGER ; n: CARDINAL ; VAR a: ARRAY OF CHAR) ;

PROCEDURE StrToInt (a: ARRAY OF CHAR ; VAR x: INTEGER) ;

PROCEDURE ReadOct (VAR x: CARDINAL) ;

PROCEDURE WriteOct (x, n: CARDINAL) ;

PROCEDURE OctToStr (x, n: CARDINAL ; VAR a: ARRAY OF CHAR) ;

PROCEDURE StrToOct (a: ARRAY OF CHAR ; VAR x: CARDINAL) ;

PROCEDURE ReadBin (VAR x: CARDINAL) ;

PROCEDURE WriteBin (x, n: CARDINAL) ;

```

```
PROCEDURE BinToStr (x, n: CARDINAL ; VAR a: ARRAY OF CHAR) ;  
  
PROCEDURE StrToBin (a: ARRAY OF CHAR ; VAR x: CARDINAL) ;  
  
PROCEDURE StrToBinInt (a: ARRAY OF CHAR ; VAR x: INTEGER) ;  
  
PROCEDURE StrToHexInt (a: ARRAY OF CHAR ; VAR x: INTEGER) ;  
  
PROCEDURE StrToOctInt (a: ARRAY OF CHAR ; VAR x: INTEGER) ;  
  
END NumberIO.
```

### 4.1.29 gm2-libs/OptLib

```

DEFINITION MODULE OptLib ;

FROM SYSTEM IMPORT ADDRESS ;
FROM DynamicStrings IMPORT String ;

TYPE
    Option ;

(*
    InitOption - constructor for Option.
*)

PROCEDURE InitOption (argc: INTEGER; argv: ADDRESS) : Option ;

(*
    KillOption - deconstructor for Option.
*)

PROCEDURE KillOption (o: Option) : Option ;

(*
    Dup - duplicate the option array inside, o.
        Notice that this does not duplicate all the contents
        (strings) of argv.
        Shallow copy of the top level indices.
*)

PROCEDURE Dup (o: Option) : Option ;

(*
    Slice - return a new option which has elements [low:high] from the
            options, o.
*)

PROCEDURE Slice (o: Option; low, high: INTEGER) : Option ;

(*
    IndexStrCmp - returns the index in the argv array which matches
                  string, s. -1 is returned if the string is not found.
*)

```

```
PROCEDURE IndexStrCmp (o: Option; s: String) : INTEGER ;

(*
  IndexStrNCmp - returns the index in the argv array where the first
                  characters are matched by string, s.
                  -1 is returned if the string is not found.
*)

PROCEDURE IndexStrNCmp (o: Option; s: String) : INTEGER ;

(*
  ConCat - returns the concatenation of a and b.
*)

PROCEDURE ConCat (a, b: Option) : Option ;

(*
  GetArgv - return the argv component of option.
*)

PROCEDURE GetArgv (o: Option) : ADDRESS ;

(*
  GetArgc - return the argc component of option.
*)

PROCEDURE GetArgc (o: Option) : INTEGER ;

END OptLib.
```

### 4.1.30 gm2-libs/PushBackInput

```
DEFINITION MODULE PushBackInput ;

FROM FIO IMPORT File ;
FROM DynamicStrings IMPORT String ;

EXPORT QUALIFIED Open, PutCh, GetCh, Error, WarnError, WarnString,
                  Close, SetDebug, GetExitStatus, PutStr,
                  PutString, GetColumnPosition, GetCurrentLine ;

(*
  Open - opens a file for reading.
*)

PROCEDURE Open (a: ARRAY OF CHAR) : File ;

(*
  GetCh - gets a character from either the push back stack or
          from file, f.
*)

PROCEDURE GetCh (f: File) : CHAR ;

(*
  PutCh - pushes a character onto the push back stack, it also
          returns the character which has been pushed.
*)

PROCEDURE PutCh (ch: CHAR) : CHAR ;

(*
  PutString - pushes a string onto the push back stack.
*)

PROCEDURE PutString (a: ARRAY OF CHAR) ;

(*
  PutStr - pushes a dynamic string onto the push back stack.
           The string, s, is not deallocated.
*)
```

```
PROCEDURE PutStr (s: String) ;
```

```
(*  
    Error - emits an error message with the appropriate file, line combination.█  
*)
```

```
PROCEDURE Error (a: ARRAY OF CHAR) ;
```

```
(*  
    WarnError - emits an error message with the appropriate file, line combination.█  
                It does not terminate but when the program finishes an exit status of█  
                1 will be issued.  
*)
```

```
PROCEDURE WarnError (a: ARRAY OF CHAR) ;
```

```
(*  
    WarnString - emits an error message with the appropriate file, line combination.█  
                It does not terminate but when the program finishes an exit status of█  
                1 will be issued.  
*)
```

```
PROCEDURE WarnString (s: String) ;
```

```
(*  
    Close - closes the opened file.  
*)
```

```
PROCEDURE Close (f: File) ;
```

```
(*  
    GetExitStatus - returns the exit status which will be 1 if any warnings were issued█  
*)
```

```
PROCEDURE GetExitStatus () : CARDINAL ;
```

```
(*  
    SetDebug - sets the debug flag on or off.  
*)
```

```
PROCEDURE SetDebug (d: BOOLEAN) ;
```

```
(*
  GetColumnPosition - returns the column position of the current character.■
*)

PROCEDURE GetColumnPosition () : CARDINAL ;

(*
  GetCurrentLine - returns the current line number.
*)

PROCEDURE GetCurrentLine () : CARDINAL ;

END PushBackInput.
```

### 4.1.31 gm2-libs/RTExceptions

```

DEFINITION MODULE RTExceptions ;

(* Runtime exception handler routines.  This should
   be considered as a system module for GNU Modula-2
   and allow the compiler to interface with exception
   handling.  *)

FROM SYSTEM IMPORT ADDRESS ;
EXPORT QUALIFIED EHBlock,
    Raise, SetExceptionBlock, GetExceptionBlock,
    GetTextBuffer, GetTextBufferSize, GetNumber,
    InitExceptionBlock, KillExceptionBlock,
    PushHandler, PopHandler,
    BaseExceptionsThrow, DefaultErrorCatch,
    IsInExceptionState, SetExceptionState,
    SwitchExceptionState, GetBaseExceptionBlock,
    SetExceptionSource, GetExceptionSource ;

TYPE
    EHBlock ;
    ProcedureHandler = PROCEDURE ;

(*
   Raise - invoke the exception handler associated with, number,
           in the active EHBlock.  It keeps a record of the number
           and message in the EHBlock for later use.
   *)

PROCEDURE Raise (number: CARDINAL;
    file: ADDRESS; line: CARDINAL;
    column: CARDINAL; function: ADDRESS;
    message: ADDRESS) <* noreturn *> ;

(*
   SetExceptionBlock - sets, source, as the active EHB.
   *)

PROCEDURE SetExceptionBlock (source: EHBlock) ;

(*
   GetExceptionBlock - returns the active EHB.
   *)

```

```
PROCEDURE GetExceptionBlock () : EHBlock ;

(*
  GetTextBuffer - returns the address of the EHB buffer.
*)

PROCEDURE GetTextBuffer (e: EHBlock) : ADDRESS ;

(*
  GetTextBufferSize - return the size of the EHB text buffer.
*)

PROCEDURE GetTextBufferSize (e: EHBlock) : CARDINAL ;

(*
  GetNumber - return the exception number associated with,
              source.
*)

PROCEDURE GetNumber (source: EHBlock) : CARDINAL ;

(*
  InitExceptionBlock - creates and returns a new exception block.
*)

PROCEDURE InitExceptionBlock () : EHBlock ;

(*
  KillExceptionBlock - destroys the EHB, e, and all its handlers.
*)

PROCEDURE KillExceptionBlock (e: EHBlock) : EHBlock ;

(*
  PushHandler - install a handler in EHB, e.
*)

PROCEDURE PushHandler (e: EHBlock; number: CARDINAL; p: ProcedureHandler) ;■
```

```
(*
  PopHandler - removes the handler associated with, number, from
               EHB, e.
*)

PROCEDURE PopHandler (e: EHBlock; number: CARDINAL) ;

(*
  DefaultErrorCatch - displays the current error message in
                     the current exception block and then
                     calls HALT.
*)

PROCEDURE DefaultErrorCatch ;

(*
  BaseExceptionsThrow - configures the Modula-2 exceptions to call
                       THROW which in turn can be caught by an
                       exception block. If this is not called then
                       a Modula-2 exception will simply call an
                       error message routine and then HALT.
*)

PROCEDURE BaseExceptionsThrow ;

(*
  IsInExceptionState - returns TRUE if the program is currently
                     in the exception state.
*)

PROCEDURE IsInExceptionState () : BOOLEAN ;

(*
  SetExceptionState - returns the current exception state and
                    then sets the current exception state to,
                    to.
*)

PROCEDURE SetExceptionState (to: BOOLEAN) : BOOLEAN ;

(*
  SwitchExceptionState - assigns, from, with the current exception
```

```
                                state and then assigns the current exception
                                to, to.
*)

PROCEDURE SwitchExceptionState (VAR from: BOOLEAN; to: BOOLEAN) ;

(*
    GetBaseExceptionBlock - returns the initial language exception block
                           created.
*)

PROCEDURE GetBaseExceptionBlock () : EHBlock ;

(*
    SetExceptionSource - sets the current exception source to, source.
*)

PROCEDURE SetExceptionSource (source: ADDRESS) ;

(*
    GetExceptionSource - returns the current exception source.
*)

PROCEDURE GetExceptionSource () : ADDRESS ;

END RTEExceptions.
```

## 4.1.32 gm2-libs/RTint

```

DEFINITION MODULE RTint ;

(* Provides users of the COROUTINES library with the
   ability to create interrupt sources based on
   file descriptors and timeouts. *)

FROM SYSTEM IMPORT ADDRESS ;

TYPE
  DispatchVector = PROCEDURE (CARDINAL, CARDINAL, ADDRESS) ;

(*
   InitInputVector - returns an interrupt vector which is associated
                     with the file descriptor, fd.
   *)

PROCEDURE InitInputVector (fd: INTEGER; pri: CARDINAL) : CARDINAL ;

(*
   InitOutputVector - returns an interrupt vector which is associated
                     with the file descriptor, fd.
   *)

PROCEDURE InitOutputVector (fd: INTEGER; pri: CARDINAL) : CARDINAL ;

(*
   InitTimeVector - returns an interrupt vector associated with
                   the relative time.
   *)

PROCEDURE InitTimeVector (micro, secs: CARDINAL; pri: CARDINAL) : CARDINAL ;

(*
   ReArmTimeVector - reprimes the vector, vec, to deliver an interrupt
                   at the new relative time.
   *)

PROCEDURE ReArmTimeVector (vec: CARDINAL; micro, secs: CARDINAL) ;

(*

```

```

    GetTimeVector - assigns, micro, and, secs, with the remaining
                    time before this interrupt will expire.
                    This value is only updated when a Listen
                    occurs.
*)

PROCEDURE GetTimeVector (vec: CARDINAL; VAR micro, secs: CARDINAL) ;

(*
    AttachVector - adds the pointer, p, to be associated with the interrupt
                    vector. It returns the previous value attached to this
                    vector.
*)

PROCEDURE AttachVector (vec: CARDINAL; ptr: ADDRESS) : ADDRESS ;

(*
    IncludeVector - includes, vec, into the dispatcher list of
                    possible interrupt causes.
*)

PROCEDURE IncludeVector (vec: CARDINAL) ;

(*
    ExcludeVector - excludes, vec, from the dispatcher list of
                    possible interrupt causes.
*)

PROCEDURE ExcludeVector (vec: CARDINAL) ;

(*
    Listen - will either block indefinitely (until an interrupt)
             or alternatively will test to see whether any interrupts
             are pending.
             If a pending interrupt was found then, call, is called
             and then this procedure returns.
             It only listens for interrupts > pri.
*)

PROCEDURE Listen (untilInterrupt: BOOLEAN;
                  call: DispatchVector;
                  pri: CARDINAL) ;

```

```
(*  
  Init - allows the user to force the initialize order.  
*)  
  
PROCEDURE Init ;  
  
END RTint.
```

### 4.1.33 gm2-libs/SArgs

```
DEFINITION MODULE SArgs ;

FROM DynamicStrings IMPORT String ;
EXPORT QUALIFIED GetArg, Narg ;

(*
  GetArg - returns the nth argument from the command line.
           The success of the operation is returned.
           If TRUE is returned then the string, s, contains a
           new string, otherwise s is set to NIL.
*)

PROCEDURE GetArg (VAR s: String ; n: CARDINAL) : BOOLEAN ;

(*
  Narg - returns the number of arguments available from
         command line.
*)

PROCEDURE Narg() : CARDINAL ;

END SArgs.
```

#### 4.1.34 gm2-libs/SCmdArgs

```
DEFINITION MODULE SCmdArgs ;

FROM DynamicStrings IMPORT String ;

EXPORT QUALIFIED GetArg, Narg ;

(*
  GetArg - returns the nth argument from the command line, CmdLine
           the success of the operation is returned.
*)

PROCEDURE GetArg (CmdLine: String;
                  n: CARDINAL; VAR Argi: String) : BOOLEAN ;

(*
  Narg - returns the number of arguments available from
         command line, CmdLine.
*)

PROCEDURE Narg (CmdLine: String) : CARDINAL ;

END SCmdArgs.
```

#### 4.1.35 gm2-libs/SEnvironment

```
DEFINITION MODULE SEnvironment ;

FROM DynamicStrings IMPORT String ;
EXPORT QUALIFIED GetEnvironment ;

(*
  GetEnvironment - gets the environment variable Env and places
                  a copy of its value into String, dest.
                  It returns TRUE if the string Env was found in
                  the processes environment.
*)

PROCEDURE GetEnvironment (Env: String;
                        VAR dest: String) : BOOLEAN ;

(*
  PutEnvironment - change or add an environment variable definition EnvDef.
                  TRUE is returned if the environment variable was
                  set or changed successfully.
*)

PROCEDURE PutEnvironment (EnvDef: String) : BOOLEAN ;

END SEnvironment.
```

### 4.1.36 gm2-libs/SFIO

```

DEFINITION MODULE SFIO ;

FROM DynamicStrings IMPORT String ;
FROM FIO IMPORT File ;

EXPORT QUALIFIED OpenToRead, OpenToWrite, OpenForRandom, Exists, WriteS, ReadS ;

(*
  Exists - returns TRUE if a file named, fname exists for reading.
*)

PROCEDURE Exists (fname: String) : BOOLEAN ;

(*
  OpenToRead - attempts to open a file, fname, for reading and
               it returns this file.
               The success of this operation can be checked by
               calling IsNoError.
*)

PROCEDURE OpenToRead (fname: String) : File ;

(*
  OpenToWrite - attempts to open a file, fname, for write and
                it returns this file.
                The success of this operation can be checked by
                calling IsNoError.
*)

PROCEDURE OpenToWrite (fname: String) : File ;

(*
  OpenForRandom - attempts to open a file, fname, for random access
                  read or write and it returns this file.
                  The success of this operation can be checked by
                  calling IsNoError.
                  towrite, determines whether the file should be
                  opened for writing or reading.
                  if towrite is TRUE or whether the previous file should
                  be left alone, allowing this descriptor to seek
                  and modify an existing file.
*)

```

\*)

PROCEDURE OpenForRandom (fname: String; towrite, newfile: BOOLEAN) : File ;

(\*

WriteS - writes a string, s, to, file. It returns the String, s.

\*)

PROCEDURE WriteS (file: File; s: String) : String ;

(\*

ReadS - reads a string, s, from, file. It returns the String, s.

It stops reading the string at the end of line or end of file.

It consumes the newline at the end of line but does not place  
this into the returned string.

\*)

PROCEDURE ReadS (file: File) : String ;

END SFIO.

#### 4.1.37 gm2-libs/SMathLib0

```
DEFINITION MODULE SMathLib0 ;

CONST
  pi    = 3.1415926535897932384626433832795028841972;
  exp1  = 2.7182818284590452353602874713526624977572;

PROCEDURE __BUILTIN__ sqrt (x: SHORTREAL) : SHORTREAL ;
PROCEDURE exp (x: SHORTREAL) : SHORTREAL ;
PROCEDURE ln (x: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ sin (x: SHORTREAL) : SHORTREAL ;
PROCEDURE __BUILTIN__ cos (x: SHORTREAL) : SHORTREAL ;
PROCEDURE tan (x: SHORTREAL) : SHORTREAL ;
PROCEDURE arctan (x: SHORTREAL) : SHORTREAL ;
PROCEDURE entier (x: SHORTREAL) : INTEGER ;

END SMathLib0.
```



```

PROCEDURE TSIZE (<type>) : CARDINAL;
  (* Returns the number of BYTES used to store a value of the
     specified <type>.
  *)

PROCEDURE ROTATE (val: <a set type>;
                  num: INTEGER): <type of first parameter>;
  (* Returns a bit sequence obtained from val by rotating up/right
     or down/right by the absolute value of num. The direction is
     down/right if the sign of num is negative, otherwise the direction
     is up/left.
  *)

PROCEDURE SHIFT (val: <a set type>;
                 num: INTEGER): <type of first parameter>;
  (* Returns a bit sequence obtained from val by shifting up/left
     or down/right by the absolute value of num, introducing
     zeros as necessary. The direction is down/right if the sign of
     num is negative, otherwise the direction is up/left.
  *)

PROCEDURE THROW (i: INTEGER) <* noreturn *> ;
  (*
     THROW is a GNU extension and was not part of the PIM or ISO
     standards. It throws an exception which will be caught by the
     EXCEPT block (assuming it exists). This is a compiler builtin
     function which interfaces to the GCC exception handling runtime
     system.
     GCC uses the term throw, hence the naming distinction between
     the GCC builtin and the Modula-2 runtime library procedure Raise.
     The later library procedure Raise will call SYSTEM.THROW after
     performing various housekeeping activities.
  *)

PROCEDURE TBITSIZE (<type>) : CARDINAL ;
  (* Returns the minimum number of bits necessary to represent
     <type>. This procedure function is only useful for determining
     the number of bits used for any type field within a packed RECORD.
     It is not particularly useful elsewhere since <type> might be
     optimized for speed, for example a BOOLEAN could occupy a WORD.
  *)

  *)

```

(\* The following procedures are invoked by GNU Modula-2 to shift non word sized set types. They are not strictly part of the core PIM Modula-2, however they are used to implement the SHIFT procedure defined above,

which are in turn used by the Logitech compatible libraries.

Users will access these procedures by using the procedure SHIFT above and GNU Modula-2 will map SHIFT onto one of the following procedures.

\*)

(\*

ShiftVal - is a runtime procedure whose job is to implement the SHIFT procedure of ISO SYSTEM. GNU Modula-2 will inline a SHIFT of a single WORD sized set and will only call this routine for larger sets.

\*)

```
PROCEDURE ShiftVal (VAR s, d: ARRAY OF BITSET;
                   SetSizeInBits: CARDINAL;
                   ShiftCount: INTEGER) ;
```

(\*

ShiftLeft - performs the shift left for a multi word set. This procedure might be called by the back end of GNU Modula-2 depending whether amount is known at compile time.

\*)

```
PROCEDURE ShiftLeft (VAR s, d: ARRAY OF BITSET;
                   SetSizeInBits: CARDINAL;
                   ShiftCount: CARDINAL) ;
```

(\*

ShiftRight - performs the shift left for a multi word set. This procedure might be called by the back end of GNU Modula-2 depending whether amount is known at compile time.

\*)

```
PROCEDURE ShiftRight (VAR s, d: ARRAY OF BITSET;
                    SetSizeInBits: CARDINAL;
                    ShiftCount: CARDINAL) ;
```

(\*

RotateVal - is a runtime procedure whose job is to implement the ROTATE procedure of ISO SYSTEM. GNU Modula-2 will inline a ROTATE of a single WORD (or less) sized set and will only call this routine for larger



### 4.1.39 gm2-libs/Scan

```
DEFINITION MODULE Scan ;

(* Provides a primitive symbol fetching from input.
   Symbols are delimited by spaces and tabs.
   Limitation only allows one source file at
   a time to deliver symbols.  *)

EXPORT QUALIFIED GetNextSymbol, WriteError,
                  OpenSource, CloseSource,
                  TerminateOnError, DefineComments ;

(* OpenSource - opens a source file for reading. *)

PROCEDURE OpenSource (a: ARRAY OF CHAR) : BOOLEAN ;

(* CloseSource - closes the current source file from reading. *)

PROCEDURE CloseSource ;

(* GetNextSymbol gets the next source symbol and returns it in a. *)

PROCEDURE GetNextSymbol (VAR a: ARRAY OF CHAR) ;

(* WriteError writes a message, a, under the source line, which
   attempts to pinpoint the Symbol at fault. *)

PROCEDURE WriteError (a: ARRAY OF CHAR) ;

(*
   TerminateOnError - exits with status 1 if we call WriteError.
   *)

PROCEDURE TerminateOnError ;

(*
   DefineComments - defines the start of comments within the source
   file.
```

The characters in Start define the comment start and characters in End define the end.

The BOOLEAN eoln determine whether the comment is terminated by end of line. If eoln is TRUE then End is ignored.

If this procedure is never called then no comments are allowed.

\*)

PROCEDURE DefineComments (Start, End: ARRAY OF CHAR; eoln: BOOLEAN) ;

END Scan.

## 4.1.40 gm2-libs/Selective

```

DEFINITION MODULE Selective ;

FROM SYSTEM IMPORT ADDRESS ;

EXPORT QUALIFIED SetOfFd, Timeval,
    InitSet, KillSet, InitTime, KillTime,
    GetTime, SetTime,
    FdZero, FdSet, FdClr, FdIsSet, Select,
    MaxFdsPlusOne, WriteCharRaw, ReadCharRaw,
    GetTimeOfDay ;

TYPE
    SetOfFd = ADDRESS ;      (* Hidden type in Selective.c *)
    Timeval = ADDRESS ;      (* Hidden type in Selective.c *)

PROCEDURE Select (nooffds: CARDINAL;
    readfds, writefds, exceptfds: SetOfFd;
    timeout: Timeval) : INTEGER ;

PROCEDURE InitTime (sec, usec: CARDINAL) : Timeval ;
PROCEDURE KillTime (t: Timeval) : Timeval ;
PROCEDURE GetTime (t: Timeval; VAR sec, usec: CARDINAL) ;
PROCEDURE SetTime (t: Timeval; sec, usec: CARDINAL) ;
PROCEDURE InitSet () : SetOfFd ;
PROCEDURE KillSet (s: SetOfFd) : SetOfFd ;
PROCEDURE FdZero (s: SetOfFd) ;
PROCEDURE FdSet (fd: INTEGER; s: SetOfFd) ;
PROCEDURE FdClr (fd: INTEGER; s: SetOfFd) ;
PROCEDURE FdIsSet (fd: INTEGER; s: SetOfFd) : BOOLEAN ;
PROCEDURE MaxFdsPlusOne (a, b: INTEGER) : INTEGER ;

(* you must use the raw routines with select - not the FIO buffered routines *)
PROCEDURE WriteCharRaw (fd: INTEGER; ch: CHAR) ;
PROCEDURE ReadCharRaw (fd: INTEGER) : CHAR ;

(*
    GetTimeOfDay - fills in a record, Timeval, filled in with the
                    current system time in seconds and microseconds.
                    It returns zero (see man 3p gettimeofday)
*)

PROCEDURE GetTimeOfDay (tv: Timeval) : INTEGER ;

```

END Selective.

#### 4.1.41 gm2-libs/StdIO

```
DEFINITION MODULE StdIO ;

EXPORT QUALIFIED ProcRead, ProcWrite,
                  Read, Write,
                  PushOutput, PopOutput, GetCurrentOutput,
                  PushInput, PopInput, GetCurrentInput ;

TYPE
  ProcWrite = PROCEDURE (CHAR) ;
  ProcRead  = PROCEDURE (VAR CHAR) ;

(*
  Read - is the generic procedure that all higher application layers
         should use to receive a character.
*)

PROCEDURE Read (VAR ch: CHAR) ;

(*
  Write - is the generic procedure that all higher application layers
         should use to emit a character.
*)

PROCEDURE Write (ch: CHAR) ;

(*
  PushOutput - pushes the current Write procedure onto a stack,
              any future references to Write will actually invoke
              procedure, p.
*)

PROCEDURE PushOutput (p: ProcWrite) ;

(*
  PopOutput - restores Write to use the previous output procedure.
*)

PROCEDURE PopOutput ;
```

```
(*
  GetCurrentOutput - returns the current output procedure.
*)

PROCEDURE GetCurrentOutput () : ProcWrite ;

(*
  PushInput - pushes the current Read procedure onto a stack,
              any future references to Read will actually invoke
              procedure, p.
*)

PROCEDURE PushInput (p: ProcRead) ;

(*
  PopInput - restores Write to use the previous output procedure.
*)

PROCEDURE PopInput ;

(*
  GetCurrentInput - returns the current input procedure.
*)

PROCEDURE GetCurrentInput () : ProcRead ;

END StdIO.
```

#### 4.1.42 gm2-libs/Storage

```
DEFINITION MODULE Storage ;

FROM SYSTEM IMPORT ADDRESS ;

EXPORT QUALIFIED ALLOCATE, DEALLOCATE, REALLOCATE, Available ;


(*
  ALLOCATE - attempt to allocate memory from the heap.
             NIL is returned in, a, if ALLOCATE fails.
*)

PROCEDURE ALLOCATE (VAR a: ADDRESS ; Size: CARDINAL) ;


(*
  DEALLOCATE - return, Size, bytes to the heap.
              The variable, a, is set to NIL.
*)

PROCEDURE DEALLOCATE (VAR a: ADDRESS ; Size: CARDINAL) ;


(*
  REALLOCATE - attempts to reallocate storage. The address,
              a, should either be NIL in which case ALLOCATE
              is called, or alternatively it should have already
              been initialized by ALLOCATE. The allocated storage
              is resized accordingly.
*)

PROCEDURE REALLOCATE (VAR a: ADDRESS; Size: CARDINAL) ;


(*
  Available - returns TRUE if, Size, bytes can be allocated.
*)

PROCEDURE Available (Size: CARDINAL) : BOOLEAN ;

END Storage.
```

#### 4.1.43 gm2-libs/StrCase

```
DEFINITION MODULE StrCase ;

EXPORT QUALIFIED StrToUpperCase, StrToLowerCase, Cap, Lower ;

(*
  StrToUpperCase - converts string, a, to uppercase returning the
                  result in, b.
*)

PROCEDURE StrToUpperCase (a: ARRAY OF CHAR ; VAR b: ARRAY OF CHAR) ;

(*
  StrToLowerCase - converts string, a, to lowercase returning the
                  result in, b.
*)

PROCEDURE StrToLowerCase (a: ARRAY OF CHAR ; VAR b: ARRAY OF CHAR) ;

(*
  Cap - converts a lower case character into a capital character.
        If the character is not a lower case character 'a'..'z'
        then the character is simply returned unaltered.
*)

PROCEDURE Cap (ch: CHAR) : CHAR ;

(*
  Lower - converts an upper case character into a lower case character.
          If the character is not an upper case character 'A'..'Z'
          then the character is simply returned unaltered.
*)

PROCEDURE Lower (ch: CHAR) : CHAR ;

END StrCase.
```

#### 4.1.44 gm2-libs/StrIO

```
DEFINITION MODULE StrIO ;

EXPORT QUALIFIED ReadString, WriteString,
                  WriteLn ;

(*
  WriteLn - writes a carriage return and a newline
           character.
*)

PROCEDURE WriteLn ;

(*
  ReadString - reads a sequence of characters into a string.
              Line editing accepts Del, Ctrl H, Ctrl W and
              Ctrl U.
*)

PROCEDURE ReadString (VAR a: ARRAY OF CHAR) ;

(*
  WriteString - writes a string to the default output.
*)

PROCEDURE WriteString (a: ARRAY OF CHAR) ;

END StrIO.
```

**4.1.45 gm2-libs/StrLib**

```
DEFINITION MODULE StrLib ;
```

```
EXPORT QUALIFIED StrConCat, StrLen, StrCopy, StrEqual, StrLess,  
                  IsSubString, StrRemoveWhitePrefix ;
```

```
(*  
  StrConCat - combines a and b into c.  
*)
```

```
PROCEDURE StrConCat (a, b: ARRAY OF CHAR; VAR c: ARRAY OF CHAR) ;
```

```
(*  
  StrLess - returns TRUE if string, a, alphabetically occurs before  
            string, b.  
*)
```

```
PROCEDURE StrLess (a, b: ARRAY OF CHAR) : BOOLEAN ;
```

```
(*  
  StrEqual - performs a = b on two strings.  
*)
```

```
PROCEDURE StrEqual (a, b: ARRAY OF CHAR) : BOOLEAN ;
```

```
(*  
  StrLen - returns the length of string, a.  
*)
```

```
PROCEDURE StrLen (a: ARRAY OF CHAR) : CARDINAL ;
```

```
(*  
  StrCopy - copy string src into string dest providing dest is large enough.■  
            If dest is smaller than a then src then the string is truncated when■  
            dest is full. Add a nul character if there is room in dest.■  
*)
```

```
PROCEDURE StrCopy (src: ARRAY OF CHAR ; VAR dest: ARRAY OF CHAR) ;
```

```
(*
```

```
    IsSubString - returns true if b is a subcomponent of a.
*)

PROCEDURE IsSubString (a, b: ARRAY OF CHAR) : BOOLEAN ;

(*
    StrRemoveWhitePrefix - copies string, into string, b, excluding any white
                           space in front of a.
*)

PROCEDURE StrRemoveWhitePrefix (a: ARRAY OF CHAR; VAR b: ARRAY OF CHAR) ;

END StrLib.
```

#### 4.1.46 gm2-libs/String

```
DEFINITION MODULE String ;

FROM DynamicStrings IMPORT String ;
FROM FIO IMPORT File ;

PROCEDURE Write (f: File; str: String) ;
PROCEDURE WriteLn (f: File) ;

END String.
```

## 4.1.47 gm2-libs/StringConvert

```
DEFINITION MODULE StringConvert ;
```

```
FROM DynamicStrings IMPORT String ;
EXPORT QUALIFIED IntegerToString, StringToInteger,
StringToLongInteger, LongIntegerToString,
StringToCardinal, CardinalToString,
StringToLongCardinal, LongCardinalToString,
StringToShortCardinal, ShortCardinalToString,
StringToLongreal, LongrealToString,
ToSigFig,
stoi, itos, ctos, stoc, hstoi, ostoi, bstoi,
hstoc, ostoc, bstoc,
stor, stolr ;
```

```
(*
IntegerToString - converts INTEGER, i, into a String. The field with
                  can be specified if non zero. Leading characters
                  are defined by padding and this function will
                  prepend a + if sign is set to TRUE.
                  The base allows the caller to generate binary,
                  octal, decimal, hexadecimal numbers.
                  The value of lower is only used when hexadecimal
                  numbers are generated and if TRUE then digits
                  abcdef are used, and if FALSE then ABCDEF are used.
*)
```

```
PROCEDURE IntegerToString (i: INTEGER; width: CARDINAL; padding: CHAR; sign: BOOLEAN;
                          base: CARDINAL; lower: BOOLEAN) : String ;
```

```
(*
CardinalToString - converts CARDINAL, c, into a String. The field
                  width can be specified if non zero. Leading
                  characters are defined by padding.
                  The base allows the caller to generate binary,
                  octal, decimal, hexadecimal numbers.
                  The value of lower is only used when hexadecimal
                  numbers are generated and if TRUE then digits
                  abcdef are used, and if FALSE then ABCDEF are used.
*)
```

```
PROCEDURE CardinalToString (c: CARDINAL; width: CARDINAL; padding: CHAR;
                          base: CARDINAL; lower: BOOLEAN) : String ;
```

```

(*)
    StringToInteger - converts a string, s, of, base, into an INTEGER.
                     Leading white space is ignored. It stops converting
                     when either the string is exhausted or if an illegal
                     numeral is found.
                     The parameter found is set TRUE if a number was found.
*)

PROCEDURE StringToInteger (s: String; base: CARDINAL; VAR found: BOOLEAN) : INTEGER ;

(*)
    StringToCardinal - converts a string, s, of, base, into a CARDINAL.
                     Leading white space is ignored. It stops converting
                     when either the string is exhausted or if an illegal
                     numeral is found.
                     The parameter found is set TRUE if a number was found.
*)

PROCEDURE StringToCardinal (s: String; base: CARDINAL; VAR found: BOOLEAN) : CARDINAL

(*)
    LongIntegerToString - converts LONGINT, i, into a String. The field width
                        can be specified if non zero. Leading characters
                        are defined by padding and this function will
                        prepend a + if sign is set to TRUE.
                        The base allows the caller to generate binary,
                        octal, decimal, hexadecimal numbers.
                        The value of lower is only used when hexadecimal
                        numbers are generated and if TRUE then digits
                        abcdef are used, and if FALSE then ABCDEF are used.
*)

PROCEDURE LongIntegerToString (i: LONGINT; width: CARDINAL; padding: CHAR;
                               sign: BOOLEAN; base: CARDINAL; lower: BOOLEAN) : String

(*)
    StringToLongInteger - converts a string, s, of, base, into an LONGINT.
                        Leading white space is ignored. It stops converting
                        when either the string is exhausted or if an illegal
                        numeral is found.
                        The parameter found is set TRUE if a number was found.
*)

```

```
PROCEDURE StringToLongInteger (s: String; base: CARDINAL; VAR found: BOOLEAN) : LONGIN
```

```
(*
  LongCardinalToString - converts LONGCARD, c, into a String. The field
                        width can be specified if non zero. Leading
                        characters are defined by padding.
                        The base allows the caller to generate binary,
                        octal, decimal, hexadecimal numbers.
                        The value of lower is only used when hexadecimal
                        numbers are generated and if TRUE then digits
                        abcdef are used, and if FALSE then ABCDEF are used.
*)
```

```
PROCEDURE LongCardinalToString (c: LONGCARD; width: CARDINAL; padding: CHAR;
                                base: CARDINAL; lower: BOOLEAN) : String ;
```

```
(*
  StringToLongCardinal - converts a string, s, of, base, into a LONGCARD.
                        Leading white space is ignored. It stops converting
                        when either the string is exhausted or if an illegal
                        numeral is found.
                        The parameter found is set TRUE if a number was found.
*)
```

```
PROCEDURE StringToLongCardinal (s: String; base: CARDINAL; VAR found: BOOLEAN) : LONGC
```

```
(*
  ShortCardinalToString - converts SHORTCARD, c, into a String. The field
                        width can be specified if non zero. Leading
                        characters are defined by padding.
                        The base allows the caller to generate binary,
                        octal, decimal, hexadecimal numbers.
                        The value of lower is only used when hexadecimal
                        numbers are generated and if TRUE then digits
                        abcdef are used, and if FALSE then ABCDEF are used.
*)
```

```
PROCEDURE ShortCardinalToString (c: SHORTCARD; width: CARDINAL; padding: CHAR;
                                base: CARDINAL; lower: BOOLEAN) : String ;
```

```
(*
  StringToShortCardinal - converts a string, s, of, base, into a SHORTCARD.
*)
```

Leading white space is ignored. It stops converting when either the string is exhausted or if an illegal numeral is found.

The parameter found is set TRUE if a number was found.

\*)

```
PROCEDURE StringToShortCardinal (s: String; base: CARDINAL;
                                VAR found: BOOLEAN) : SHORTCARD ;
```

(\*  
  stoi - decimal string to INTEGER  
\*)

```
PROCEDURE stoi (s: String) : INTEGER ;
```

(\*  
  itos - integer to decimal string.  
\*)

```
PROCEDURE itos (i: INTEGER; width: CARDINAL; padding: CHAR; sign: BOOLEAN) : String ;
```

(\*  
  ctos - cardinal to decimal string.  
\*)

```
PROCEDURE ctos (c: CARDINAL; width: CARDINAL; padding: CHAR) : String ;
```

(\*  
  stoc - decimal string to CARDINAL  
\*)

```
PROCEDURE stoc (s: String) : CARDINAL ;
```

(\*  
  hstoi - hexadecimal string to INTEGER  
\*)

```
PROCEDURE hstoi (s: String) : INTEGER ;
```

(\*  
  ostoi - octal string to INTEGER

\*)

PROCEDURE ostoi (s: String) : INTEGER ;

(\*

    bstoi - binary string to INTEGER

\*)

PROCEDURE bstoi (s: String) : INTEGER ;

(\*

    hstoc - hexadecimal string to CARDINAL

\*)

PROCEDURE hstoc (s: String) : CARDINAL ;

(\*

    ostoc - octal string to CARDINAL

\*)

PROCEDURE ostoc (s: String) : CARDINAL ;

(\*

    bstoc - binary string to CARDINAL

\*)

PROCEDURE bstoc (s: String) : CARDINAL ;

(\*

    StringToLongreal - returns a LONGREAL and sets found to TRUE  
                          if a legal number is seen.

\*)

PROCEDURE StringToLongreal (s: String; VAR found: BOOLEAN) : LONGREAL ;

(\*

    LongrealToString - converts a LONGREAL number, Real, which has,  
                          TotalWidth, and FractionWidth into a string.

So for example:

```

LongrealToString(1.0, 4, 2) -> '1.00'
LongrealToString(12.3, 5, 2) -> '12.30'
LongrealToString(12.3, 6, 2) -> ' 12.30'
LongrealToString(12.3, 6, 3) -> '12.300'

```

if total width is too small then the fraction becomes truncated.

```

LongrealToString(12.3, 5, 3) -> '12.30'

```

If TotalWidth is 0 then the function will return the value of x which is converted into as a fixed point number with exhaustive precision.

\*)

```

PROCEDURE LongrealToString (x: LONGREAL;
                           TotalWidth, FractionWidth: CARDINAL) : String ;■

```

```

(*)
  stor - returns a REAL given a string.
*)

```

```

PROCEDURE stor (s: String) : REAL ;

```

```

(*)
  stolr - returns a LONGREAL given a string.
*)

```

```

PROCEDURE stolr (s: String) : LONGREAL ;

```

```

(*)
  ToSigFig - returns a floating point or base 10 integer
             string which is accurate to, n, significant
             figures. It will return a new String
             and, s, will be destroyed.

```

So: 12.345

rounded to the following significant figures yields

5	12.345
4	12.34

```

        3      12.3
        2      12
        1      10
*)

PROCEDURE ToSigFig (s: String; n: CARDINAL) : String ;

(*
    ToDecimalPlaces - returns a floating point or base 10 integer
                     string which is accurate to, n, decimal
                     places. It will return a new String
                     and, s, will be destroyed.
                     Decimal places yields, n, digits after
                     the .

                     So:  12.345

                     rounded to the following decimal places yields

                     5      12.34500
                     4      12.3450
                     3      12.345
                     2      12.34
                     1      12.3
*)

PROCEDURE ToDecimalPlaces (s: String; n: CARDINAL) : String ;

END StringConvert.
```

#### 4.1.48 gm2-libs/StringFileSysOp

```
DEFINITION MODULE StringFileSysOp ;

FROM DynamicStrings IMPORT String ;
FROM CFileSysOp IMPORT AccessMode ;


PROCEDURE Exists (filename: String) : BOOLEAN ;
PROCEDURE IsDir (dirname: String) : BOOLEAN ;
PROCEDURE IsFile (filename: String) : BOOLEAN ;
PROCEDURE Unlink (filename: String) : BOOLEAN ;
PROCEDURE Access (pathname: String; mode: AccessMode) : AccessMode ;


END StringFileSysOp.
```

#### 4.1.49 gm2-libs/SysExceptions

```
DEFINITION MODULE SysExceptions ;

(* Provides a mechanism for the underlying libraries to
   configure the exception routines. This mechanism
   is used by both the ISO and PIM libraries.
   It is written to be ISO compliant and this also
   allows for mixed dialect projects. *)

FROM SYSTEM IMPORT ADDRESS ;

TYPE
  PROCEXCEPTION = PROCEDURE (ADDRESS) ;

PROCEDURE InitExceptionHandler (indexf, range, casef, invalidloc,
                                function, wholevalue, wholediv,
                                realvalue, realdiv, complexvalue,
                                complexdiv, protection, systemf,
                                coroutine, exception: PROCEXCEPTION) ;

END SysExceptions.
```

#### 4.1.50 gm2-libs/SysStorage

```

DEFINITION MODULE SysStorage ;

(* Provides dynamic allocation for the system components.
   This allows the application to use the traditional Storage module
   which can be handled differently. *)

FROM SYSTEM IMPORT ADDRESS ;
EXPORT QUALIFIED ALLOCATE, DEALLOCATE, REALLOCATE, Available, Init ;

(*
   ALLOCATE - attempt to allocate memory from the heap.
               NIL is returned in, a, if ALLOCATE fails.
*)

PROCEDURE ALLOCATE (VAR a: ADDRESS ; size: CARDINAL) ;

(*
   DEALLOCATE - return, size, bytes to the heap.
               The variable, a, is set to NIL.
*)

PROCEDURE DEALLOCATE (VAR a: ADDRESS ; size: CARDINAL) ;

(*
   REALLOCATE - attempts to reallocate storage. The address,
               a, should either be NIL in which case ALLOCATE
               is called, or alternatively it should have already
               been initialized by ALLOCATE. The allocated storage
               is resized accordingly.
*)

PROCEDURE REALLOCATE (VAR a: ADDRESS; size: CARDINAL) ;

(*
   Available - returns TRUE if, size, bytes can be allocated.
*)

PROCEDURE Available (size: CARDINAL) : BOOLEAN;

(*

```

```
    Init - initializes the heap.  
          This does nothing on a GNU/Linux system.  
          But it remains here since it might be used in an  
          embedded system.  
*)  
  
PROCEDURE Init ;  
  
END SysStorage.
```

#### 4.1.51 gm2-libs/TimeString

```
DEFINITION MODULE TimeString ;
```

```
EXPORT QUALIFIED GetTimeString ;
```

```
(*  
  GetTimeString - places the time in ascii format into array, a.
```

```
*)
```

```
PROCEDURE GetTimeString (VAR a: ARRAY OF CHAR) ;
```

```
END TimeString.
```

#### 4.1.52 gm2-libs/UnixArgs

```
DEFINITION MODULE UnixArgs ;

FROM SYSTEM IMPORT ADDRESS ;

EXPORT QUALIFIED GetArgC, GetArgV, GetEnvV ;

PROCEDURE GetArgC () : INTEGER ;
PROCEDURE GetArgV () : ADDRESS ;
PROCEDURE GetEnvV () : ADDRESS ;

END UnixArgs.
```

### 4.1.53 gm2-libs/cbuiltin

```

DEFINITION MODULE FOR "C" cbuiltin ;

FROM SYSTEM IMPORT ADDRESS ;
EXPORT UNQUALIFIED alloca, memcpy,
    isfinite, isfinitef, isfinitel,
    isinf_sign, isinf_signf, isinf_signl,
        sinf, sinl, sin,
        cosf, cosl, cos,
        atan2f, atan2l, atan2,
        sqrtf, sqrtl, sqrt,
        fabsf, fabsl, fabs,
        logf, logl, log,
        expf, expl, exp,
        log10f, log10l, log10,
        exp10f, exp10l, exp10,
        ilogbf, ilogbl, ilogb,
        significand, significandf, significandl,
        modf, modff, modfl,
        nextafter, nextafterf, nextafterl,
        nexttoward, nexttowardf, nexttowardl,
        scalb, scalbf, scalbl,
        scalbn, scalbnf, scalbnl,
        scalbln, scalblnf, scalblnl,

        cabsf, cabsl, cabs,
        cargf, carg, cargl,
        conjf, conj, conjl,
        cpowf, cpow, cpowl,
        csqrtf, csqrt, csqrtl,
        cexpf, cexp, cexpl,
        clogf, clog, clogl,
        csinf, csin, csinl,
        ccosf, ccos, ccosl,
        ctanf, ctan, ctanl,
        casinf, casin, casinl,
        cacosf, cacos, cacosl,
        catanf, catan, catanl,

        index, rindex,
        memcmp, memset, memmove,
        strcat, strncat, strcpy, strncpy, strcmp, strncmp,
        strlen, strstr, strpbrk, strspn, strcspn, strchr, strrchr,

        clz, clzll,
        ctz, ctzll ;

```

```

PROCEDURE alloca (i: CARDINAL) : ADDRESS ;
PROCEDURE memcpy (dest, src: ADDRESS; n: CARDINAL) : ADDRESS ;
PROCEDURE isfinite (x: REAL) : BOOLEAN ;
PROCEDURE isfinitel (x: LONGREAL) : BOOLEAN ;
PROCEDURE isfinitef (x: SHORTREAL) : BOOLEAN ;
PROCEDURE isinf_sign (x: REAL) : BOOLEAN ;
PROCEDURE isinf_signl (x: LONGREAL) : BOOLEAN ;
PROCEDURE isinf_signf (x: SHORTREAL) : BOOLEAN ;
PROCEDURE sinf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE sin (x: REAL) : REAL ;
PROCEDURE sinl (x: LONGREAL) : LONGREAL ;
PROCEDURE cosf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE cos (x: REAL) : REAL ;
PROCEDURE cosl (x: LONGREAL) : LONGREAL ;
PROCEDURE atan2f (x, y: SHORTREAL) : SHORTREAL ;
PROCEDURE atan2 (x, y: REAL) : REAL ;
PROCEDURE atan2l (x, y: LONGREAL) : LONGREAL ;
PROCEDURE sqrtf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE sqrt (x: REAL) : REAL ;
PROCEDURE sqrtl (x: LONGREAL) : LONGREAL ;
PROCEDURE fabsf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE fabs (x: REAL) : REAL ;
PROCEDURE fabsl (x: LONGREAL) : LONGREAL ;
PROCEDURE logf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE log (x: REAL) : REAL ;
PROCEDURE logl (x: LONGREAL) : LONGREAL ;
PROCEDURE expf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE exp (x: REAL) : REAL ;
PROCEDURE expl (x: LONGREAL) : LONGREAL ;
PROCEDURE log10f (x: SHORTREAL) : SHORTREAL ;
PROCEDURE log10 (x: REAL) : REAL ;
PROCEDURE log10l (x: LONGREAL) : LONGREAL ;
PROCEDURE exp10f (x: SHORTREAL) : SHORTREAL ;
PROCEDURE exp10 (x: REAL) : REAL ;
PROCEDURE exp10l (x: LONGREAL) : LONGREAL ;
PROCEDURE ilogbf (x: SHORTREAL) : INTEGER ;
PROCEDURE ilogb (x: REAL) : INTEGER ;
PROCEDURE ilogbl (x: LONGREAL) : INTEGER ;

PROCEDURE significand (r: REAL) : REAL ;
PROCEDURE significandf (s: SHORTREAL) : SHORTREAL ;
PROCEDURE significandl (l: LONGREAL) : LONGREAL ;

PROCEDURE modf (x: REAL; VAR y: REAL) : REAL ;
PROCEDURE modff (x: SHORTREAL; VAR y: SHORTREAL) : SHORTREAL ;
PROCEDURE modfl (x: LONGREAL; VAR y: LONGREAL) : LONGREAL ;

```

```
PROCEDURE nextafter (x, y: REAL) : REAL ;
PROCEDURE nextafterf (x, y: SHORTREAL) : SHORTREAL ;
PROCEDURE nextafterl (x, y: LONGREAL) : LONGREAL ;

PROCEDURE nexttoward (x: REAL; y: LONGREAL) : REAL ;
PROCEDURE nexttowardf (x: SHORTREAL; y: LONGREAL) : SHORTREAL ;
PROCEDURE nexttowardl (x, y: LONGREAL) : LONGREAL ;

PROCEDURE scalb (x, n: REAL) : REAL ;
PROCEDURE scalbf (x, n: SHORTREAL) : SHORTREAL ;
PROCEDURE scalbl (x, n: LONGREAL) : LONGREAL ;

PROCEDURE scalbn (x: REAL; n: INTEGER) : REAL ;
PROCEDURE scalbnf (x: SHORTREAL; n: INTEGER) : SHORTREAL ;
PROCEDURE scalbnl (x: LONGREAL; n: INTEGER) : LONGREAL ;

PROCEDURE scalbln (x: REAL; n: LONGINT) : REAL ;
PROCEDURE scalblnf (x: SHORTREAL; n: LONGINT) : SHORTREAL ;
PROCEDURE scalblnl (x: LONGREAL; n: LONGINT) : LONGREAL ;

PROCEDURE cabsf (z: SHORTCOMPLEX) : SHORTREAL ;
PROCEDURE cabs (z: COMPLEX) : REAL ;
PROCEDURE cabsl (z: LONGCOMPLEX) : LONGREAL ;

PROCEDURE cargf (z: SHORTCOMPLEX) : SHORTREAL ;
PROCEDURE carg (z: COMPLEX) : REAL ;
PROCEDURE cargl (z: LONGCOMPLEX) : LONGREAL ;

PROCEDURE conjf (z: SHORTCOMPLEX) : SHORTCOMPLEX ;
PROCEDURE conj (z: COMPLEX) : COMPLEX ;
PROCEDURE conjl (z: LONGCOMPLEX) : LONGCOMPLEX ;

PROCEDURE cpowf (base: SHORTCOMPLEX; exp: SHORTREAL) : SHORTCOMPLEX ;
PROCEDURE cpow (base: COMPLEX; exp: REAL) : COMPLEX ;
PROCEDURE cpowl (base: LONGCOMPLEX; exp: LONGREAL) : LONGCOMPLEX ;

PROCEDURE csqrtf (z: SHORTCOMPLEX) : SHORTCOMPLEX ;
PROCEDURE csqrt (z: COMPLEX) : COMPLEX ;
PROCEDURE csqrtl (z: LONGCOMPLEX) : LONGCOMPLEX ;

PROCEDURE cexpf (z: SHORTCOMPLEX) : SHORTCOMPLEX ;
PROCEDURE cexp (z: COMPLEX) : COMPLEX ;
PROCEDURE cexpl (z: LONGCOMPLEX) : LONGCOMPLEX ;

PROCEDURE clogf (z: SHORTCOMPLEX) : SHORTCOMPLEX ;
PROCEDURE clog (z: COMPLEX) : COMPLEX ;
```

```

PROCEDURE clogl (z: LONGCOMPLEX) : LONGCOMPLEX ;

PROCEDURE csinf (z: SHORTCOMPLEX) : SHORTCOMPLEX ;
PROCEDURE csin (z: COMPLEX) : COMPLEX ;
PROCEDURE csinl (z: LONGCOMPLEX) : LONGCOMPLEX ;

PROCEDURE ccosf (z: SHORTCOMPLEX) : SHORTCOMPLEX ;
PROCEDURE ccos (z: COMPLEX) : COMPLEX ;
PROCEDURE ccosl (z: LONGCOMPLEX) : LONGCOMPLEX ;

PROCEDURE ctanf (z: SHORTCOMPLEX) : SHORTCOMPLEX ;
PROCEDURE ctan (z: COMPLEX) : COMPLEX ;
PROCEDURE ctanl (z: LONGCOMPLEX) : LONGCOMPLEX ;

PROCEDURE casinf (z: SHORTCOMPLEX) : SHORTCOMPLEX ;
PROCEDURE casin (z: COMPLEX) : COMPLEX ;
PROCEDURE casinl (z: LONGCOMPLEX) : LONGCOMPLEX ;

PROCEDURE cacosf (z: SHORTCOMPLEX) : SHORTCOMPLEX ;
PROCEDURE cacos (z: COMPLEX) : COMPLEX ;
PROCEDURE cacosl (z: LONGCOMPLEX) : LONGCOMPLEX ;

PROCEDURE catanf (z: SHORTCOMPLEX) : SHORTCOMPLEX ;
PROCEDURE catan (z: COMPLEX) : COMPLEX ;
PROCEDURE catanl (z: LONGCOMPLEX) : LONGCOMPLEX ;

PROCEDURE index (s: ADDRESS; c: INTEGER) : ADDRESS ;
PROCEDURE rindex (s: ADDRESS; c: INTEGER) : ADDRESS ;
PROCEDURE memcmp (s1, s2: ADDRESS; n: CARDINAL) : INTEGER ;
PROCEDURE memmove (s1, s2: ADDRESS; n: CARDINAL) : ADDRESS ;
PROCEDURE memset (s: ADDRESS; c: INTEGER; n: CARDINAL) : ADDRESS ;
PROCEDURE strcat (dest, src: ADDRESS) : ADDRESS ;
PROCEDURE strncat (dest, src: ADDRESS; n: CARDINAL) : ADDRESS ;
PROCEDURE strcpy (dest, src: ADDRESS) : ADDRESS ;
PROCEDURE strncpy (dest, src: ADDRESS; n: CARDINAL) : ADDRESS ;
PROCEDURE strcmp (s1, s2: ADDRESS) : INTEGER ;
PROCEDURE strncmp (s1, s2: ADDRESS; n: CARDINAL) : INTEGER ;
PROCEDURE strlen (s: ADDRESS) : INTEGER ;
PROCEDURE strstr (haystack, needle: ADDRESS) : ADDRESS ;
PROCEDURE strpbrk (s, accept: ADDRESS) : ADDRESS ;
PROCEDURE strspn (s, accept: ADDRESS) : CARDINAL ;
PROCEDURE strcspn (s, accept: ADDRESS) : CARDINAL ;
PROCEDURE strchr (s: ADDRESS; c: INTEGER) : ADDRESS ;
PROCEDURE strrchr (s: ADDRESS; c: INTEGER) : ADDRESS ;

PROCEDURE clz (value: CARDINAL) : INTEGER ;
PROCEDURE clzll (value: CARDINAL) : INTEGER ;

```

```
PROCEDURE ctz (value: CARDINAL) : INTEGER ;  
PROCEDURE ctzll (value: CARDINAL) : INTEGER ;
```

```
END cbuiltin.
```



```
                                longopts: ADDRESS; VAR longindex: INTEGER) : INTEGER ;■

(*
  InitOptions - constructor for empty Options.
*)

PROCEDURE InitOptions () : Options ;

(*
  KillOptions - deconstructor for empty Options.
*)

PROCEDURE KillOptions (o: Options) : Options ;

(*
  SetOption - set option[index] with {name, has_arg, flag, val}.
*)

PROCEDURE SetOption (o: Options; index: CARDINAL;
                    name: ADDRESS; has_arg: INTEGER;
                    VAR flag: INTEGER; val: INTEGER) ;

(*
  GetLongOptionArray - return a pointer to the C array containing all
                      long options.
*)

PROCEDURE GetLongOptionArray (o: Options) : ADDRESS ;

END cgetopt.
```

#### 4.1.55 gm2-libs/cxxabi

```
DEFINITION MODULE FOR "C" cxxabi ;

(* This should only be used by the compiler and it matches the
   g++ implementation. *)

FROM SYSTEM IMPORT ADDRESS ;
EXPORT UNQUALIFIED __cxa_begin_catch, __cxa_end_catch, __cxa_rethrow ;

PROCEDURE __cxa_begin_catch (a: ADDRESS) : ADDRESS ;
PROCEDURE __cxa_end_catch ;
PROCEDURE __cxa_rethrow ;

END cxxabi.
```

## 4.1.56 gm2-libs/dtoa

```

DEFINITION MODULE dtoa ;

FROM SYSTEM IMPORT ADDRESS ;

TYPE
  Mode = (maxsignificant, decimaldigits) ;

(*
  strtod - returns a REAL given a string, s.  It will set
           error to TRUE if the number is too large.
*)

PROCEDURE strtod (s: ADDRESS; VAR error: BOOLEAN) : REAL ;

(*
  dtoa - converts a REAL, d, into a string.  The address of the
         string is returned.
         mode      indicates the type of conversion required.
         ndigits   determines the number of digits according to mode.
         decpt     the position of the decimal point.
         sign      does the string have a sign?
*)

PROCEDURE dtoa (d          : REAL;
               mode       : INTEGER;
               ndigits    : INTEGER;
               VAR decpt: INTEGER;
               VAR sign : BOOLEAN) : ADDRESS ;

END dtoa.

```

#### 4.1.57 gm2-libs/errno

```
DEFINITION MODULE errno ;

CONST
    EINTR  = 4 ;    (* system call interrupted *)
    ERANGE = 34 ;   (* result is too large    *)
    EAGAIN = 11 ;   (* retry the system call  *)

PROCEDURE geterrno () : INTEGER ;

END errno.
```

## 4.1.58 gm2-libs/gdbif

```

DEFINITION MODULE gdbif ;

(* Provides interactive connectivity with gdb useful for debugging
   Modula-2 shared libraries. *)

EXPORT UNQUALIFIED sleepSpin, finishSpin, connectSpin ;

(*
   finishSpin - sets boolean mustWait to FALSE.
*)

PROCEDURE finishSpin ;

(*
   sleepSpin - waits for the boolean variable mustWait to become FALSE.
               It sleeps for a second between each test of the variable.
*)

PROCEDURE sleepSpin ;

(*
   connectSpin - breakpoint placeholder. Its only purpose is to allow users
                 to set a breakpoint. This procedure is called once
                 sleepSpin is released from its spin (via a call from
                 finishSpin).
*)

PROCEDURE connectSpin ;

END gdbif.

```

#### 4.1.59 gm2-libs/ldtoa

```

DEFINITION MODULE ldtoa ;

FROM SYSTEM IMPORT ADDRESS ;

TYPE
  Mode = (maxsignificant, decimaldigits) ;

(*
  strtold - returns a LONGREAL given a C string, s.  It will set
            error to TRUE if the number is too large or badly formed.
*)

PROCEDURE strtold (s: ADDRESS; VAR error: BOOLEAN) : LONGREAL ;

(*
  ldtoa - converts a LONGREAL, d, into a string.  The address of the
          string is returned.
          mode      indicates the type of conversion required.
          ndigits   determines the number of digits according to mode.
          decpt     the position of the decimal point.
          sign      does the string have a sign?
*)

PROCEDURE ldtoa (d          : LONGREAL;
                 mode       : INTEGER;
                 ndigits    : INTEGER;
                 VAR decpt  : INTEGER;
                 VAR sign   : BOOLEAN) : ADDRESS ;

END ldtoa.
```



```

        millitm : SHORTCARD ;
        timezone: SHORTCARD ;
        dstflag : SHORTCARD ;
    END ;

    exitP = PROCEDURE () : INTEGER ;

(*
    double atof(const char *nptr)
*)
PROCEDURE atof (nptr: ADDRESS) : REAL ;

(*
    int atoi(const char *nptr)
*)
PROCEDURE atoi (nptr: ADDRESS) : INTEGER ;

(*
    long atol(const char *nptr);
*)
PROCEDURE atol (nptr: ADDRESS) : CSSIZE_T ;

(*
    long long atoll(const char *nptr);
*)
PROCEDURE atoll (nptr: ADDRESS) : LONGINT ;

(*
    double strtod(const char *restrict nptr, char **_Nullable restrict endptr)■
*)
PROCEDURE strtod (nptr, endptr: ADDRESS) : REAL ;

(*
    float strtodf(const char *restrict nptr, char **_Nullable restrict endptr)■
*)

```

```

PROCEDURE strttof (nptr, endptr: ADDRESS) : SHORTREAL ;

(*
    long double strtold(const char *restrict nptr,
                        char **_Nullable restrict endptr)
*)

PROCEDURE strtold (nptr, endptr: ADDRESS) : LONGREAL ;

(*
    long strtol(const char *restrict nptr, char **_Nullable restrict endptr,
                int base)
*)

PROCEDURE strtol (nptr, endptr: ADDRESS; base: INTEGER) : CSSIZE_T ;

(*
    long long strtoll(const char *restrict nptr,
                      char **_Nullable restrict endptr, int base)
*)

PROCEDURE strtoll (nptr, endptr: ADDRESS; base: INTEGER) : LONGINT ;

(*
    unsigned long strtoul(const char *restrict nptr,
                          char **_Nullable restrict endptr, int base)
*)

PROCEDURE strtoul (nptr, endptr: ADDRESS; base: INTEGER) : CSIZE_T ;

(*
    unsigned long long strtoull(const char *restrict nptr,
                                char **_Nullable restrict endptr, int base)
*)

PROCEDURE strtoull (nptr, endptr: ADDRESS; base: INTEGER) : LONGCARD ;

(*
    ssize_t write (int d, void *buf, size_t nbytes)
*)

```

```
PROCEDURE write (d: INTEGER; buf: ADDRESS; nbytes: CSIZE_T) : [ CSSIZE_T ] ;■
```

```
(*
    ssize_t read (int d, void *buf, size_t nbytes)
*)
```

```
PROCEDURE read (d: INTEGER; buf: ADDRESS; nbytes: CSIZE_T) : [ CSSIZE_T ] ;■
```

```
(*
    int system(string)
    char *string;
*)
```

```
PROCEDURE system (a: ADDRESS) : [ INTEGER ] ;
```

```
(*
    abort - generate a fault

    abort() first closes all open files if possible, then sends
    an IOT signal to the process. This signal usually results
    in termination with a core dump, which may be used for
    debugging.

    It is possible for abort() to return control if is caught or
    ignored, in which case the value returned is that of the
    kill(2V) system call.
*)
```

```
PROCEDURE abort <* noreturn *> ;
```

```
(*
    malloc - memory allocator.

    void *malloc(size_t size);

    malloc() returns a pointer to a block of at least size
    bytes, which is appropriately aligned. If size is zero,
    malloc() returns a non-NULL pointer, but this pointer should
    not be dereferenced.
*)
```

```
PROCEDURE malloc (size: CSIZE_T) : ADDRESS ;
```

```

(*)
    free - memory deallocator.

    free (void *ptr);

    free() releases a previously allocated block. Its argument
    is a pointer to a block previously allocated by malloc,
    calloc, realloc, malloc, or memalign.
*)

PROCEDURE free (ptr: ADDRESS) ;

(*)
    void *realloc (void *ptr, size_t size);

    realloc changes the size of the memory block pointed to
    by ptr to size bytes. The contents will be unchanged to
    the minimum of the old and new sizes; newly allocated memory
    will be uninitialized. If ptr is NIL, the call is
    equivalent to malloc(size); if size is equal to zero, the
    call is equivalent to free(ptr). Unless ptr is NIL, it
    must have been returned by an earlier call to malloc(),
    realloc.
*)

PROCEDURE realloc (ptr: ADDRESS; size: CSIZE_T) : ADDRESS ;

(*)
    isatty - does this descriptor refer to a terminal.
*)

PROCEDURE isatty (fd: INTEGER) : INTEGER ;

(*)
    exit - returns control to the invoking process. Result, r, is
    returned.
*)

PROCEDURE exit (r: INTEGER) <* noreturn *> ;

(*)
    getenv - returns the C string for the equivalent C environment

```

```
        variable.
*)

PROCEDURE getenv (s: ADDRESS) : ADDRESS ;

(*
    putenv - change or add an environment variable.
*)

PROCEDURE putenv (s: ADDRESS) : INTEGER ;

(*
    getpid - returns the UNIX process identification number.
*)

PROCEDURE getpid () : INTEGER ;

(*
    dup - duplicates the file descriptor, d.
*)

PROCEDURE dup (d: INTEGER) : INTEGER ;

(*
    close - closes the file descriptor, d.
*)

PROCEDURE close (d: INTEGER) : [ INTEGER ] ;

(*
    open - open the file, filename with flag and mode.
*)

PROCEDURE open (filename: ADDRESS; oflag: INTEGER; mode: INTEGER) : INTEGER ;■

(*
    creat - creates a new file
*)

PROCEDURE creat (filename: ADDRESS; mode: CARDINAL) : INTEGER;
```

```

(*)
    lseek - calls unix lseek:

            off_t lseek(int fildes, off_t offset, int whence);
*)

PROCEDURE lseek (fd: INTEGER; offset: COFF_T; whence: INTEGER) : [ COFF_T ] ;■

(*)
    perror - writes errno and string. (ARRAY OF CHAR is translated onto ADDRESS).■
*)

PROCEDURE perror (string: ARRAY OF CHAR);

(*)
    readv - reads an io vector of bytes.
*)

PROCEDURE readv (fd: INTEGER; v: ADDRESS; n: INTEGER) : [ INTEGER ] ;

(*)
    writev - writes an io vector of bytes.
*)

PROCEDURE writev (fd: INTEGER; v: ADDRESS; n: INTEGER) : [ INTEGER ] ;

(*)
    getcwd - copies the absolute pathname of the
             current working directory to the array pointed to by buf,
             which is of length size.

             If the current absolute path name would require a buffer
             longer than size elements, NULL is returned, and errno is
             set to ERANGE; an application should check for this error,
             and allocate a larger buffer if necessary.
*)

PROCEDURE getcwd (buf: ADDRESS; size: CSIZE_T) : ADDRESS ;

(*)
    chown - The owner of the file specified by path or by fd is

```





```

(*)
    int snprintf(char *str, size_t size, const char *format, ...);
*)

PROCEDURE snprintf (dest: ADDRESS; size: CSIZE_T;
                    format: ARRAY OF CHAR; ...) : [ INTEGER ] ;

(*)
    setenv - sets environment variable, name, to value.
            It will overwrite an existing value if, overwrite,
            is true. It returns 0 on success and -1 for an error.
*)

PROCEDURE setenv (name: ADDRESS; value: ADDRESS; overwrite: INTEGER) : [ INTEGER ] ;■

(*)
    srand - initialize the random number seed.
*)

PROCEDURE srand (seed: INTEGER) ;

(*)
    rand - return a random integer.
*)

PROCEDURE rand () : INTEGER ;

(*)
    time - returns a pointer to the time_t value. If, a,
           is not NIL then the libc value is copied into
           memory at address, a.
*)

PROCEDURE time (a: ADDRESS) : time_t ;

(*)
    localtime - returns a pointer to the libc copy of the tm
                structure.
*)

PROCEDURE localtime (VAR t: time_t) : ADDRESS ;

```

```
(*
    ftime - return date and time.
*)

PROCEDURE ftime (VAR t: timeb) : [ INTEGER ] ;

(*
    shutdown - shutdown a socket, s.
               if how = 0, then no more reads are allowed.
               if how = 1, then no more writes are allowed.
               if how = 2, then no more reads or writes are allowed.
*)

PROCEDURE shutdown (s: INTEGER; how: INTEGER) : [ INTEGER ] ;

(*
    rename - change the name or location of a file
*)

PROCEDURE rename (oldpath, newpath: ADDRESS) : [ INTEGER ] ;

(*
    setjmp - returns 0 if returning directly, and non-zero
             when returning from longjmp using the saved
             context.
*)

PROCEDURE setjmp (env: ADDRESS) : INTEGER ;

(*
    longjmp - restores the environment saved by the last call
              of setjmp with the corresponding env argument.
              After longjmp is completed, program execution
              continues as if the corresponding call of setjmp
              had just returned the value val. The value of
              val must not be zero.
*)

PROCEDURE longjmp (env: ADDRESS; val: INTEGER) ;

(*
    atexit - execute, proc, when the function exit is called.
```

```
*)

PROCEDURE atexit (proc: exitP) : [ INTEGER ] ;

(*
  ttyname - returns a pointer to a string determining the ttyname.
*)

PROCEDURE ttyname (filedes: INTEGER) : ADDRESS ;

(*
  sleep - calling thread sleeps for seconds.
*)

PROCEDURE sleep (seconds: CARDINAL) : [ CARDINAL ] ;

(*
  execv - execute a file.
*)

PROCEDURE execv (pathname: ADDRESS; argv: ADDRESS) : [ INTEGER ] ;

END libc.
```





























































#### 4.2.8 gm2-libs-log/DebugPMD

```
DEFINITION MODULE DebugPMD ;
```

```
END DebugPMD.
```

### 4.2.9 gm2-libs-log/DebugTrace

```
DEFINITION MODULE DebugTrace ;
```

```
END DebugTrace.
```

















```
        and rereads the buffer if in modify mode.
*)

PROCEDURE Doio (VAR f: File) ;

(*
  FileNameChar - checks to see whether the character, ch, is
                  legal in a filename. nul is returned if the
                  character was illegal.
*)

PROCEDURE FileNameChar (ch: CHAR) : CHAR ;

END FileSystem.
```











```
        It ensures that the number occupies, n, characters.
        Leading spaces are added if required.
*)

PROCEDURE WriteHex (x, n: CARDINAL) ;

(*
    ReadS - returns a string which has is a sequence of characters.
           Leading white space is ignored and string is terminated
           with a character <= ' '.
*)

PROCEDURE ReadS () : String ;

(*
    WriteS - writes a String to the output device.
            It returns the string, s.
*)

PROCEDURE WriteS (s: String) : String ;

END InOut.
```



#### 4.2.17 gm2-libs-log/LongIO

```
DEFINITION MODULE LongIO ;

EXPORT QUALIFIED Done, ReadLongInt, WriteLongInt ;

VAR
    Done: BOOLEAN ;

PROCEDURE ReadLongInt (VAR i: LONGINT) ;
PROCEDURE WriteLongInt (i: LONGINT; n: CARDINAL) ;

END LongIO.
```

#### 4.2.18 gm2-libs-log/NumberConversion

```
DEFINITION MODULE NumberConversion ;
```

```
(* --fixme-- finish this. *)
```

```
END NumberConversion.
```



```
PROCEDURE RandomReal ( ) : REAL ;

(*
  RandomLongReal - return a LONGREAL number in the range 0.0..1.0
*)

PROCEDURE RandomLongReal ( ) : LONGREAL ;

END Random.
```





```
(*
  StringToReal - converts, str, into a REAL, r. The parameter, ok, is
                  set to TRUE if the conversion was successful.
*)

PROCEDURE StringToReal (str: ARRAY OF CHAR; VAR r: REAL; VAR ok: BOOLEAN) ;■

(*
  StringToLongReal - converts, str, into a LONGREAL, r. The parameter, ok, is■
                  set to TRUE if the conversion was successful.
*)

PROCEDURE StringToLongReal (str: ARRAY OF CHAR; VAR r: LONGREAL; VAR ok: BOOLEAN) ;■

END RealConversions.
```

### 4.2.21 gm2-libs-log/RealInOut

```

DEFINITION MODULE RealInOut ;

EXPORT QUALIFIED SetNoOfDecimalPlaces,
                  ReadReal, WriteReal, WriteRealOct,
                  ReadLongReal, WriteLongReal, WriteLongRealOct,
                  ReadShortReal, WriteShortReal, WriteShortRealOct,
                  Done ;

CONST
  DefaultDecimalPlaces = 6 ;

VAR
  Done: BOOLEAN ;

(*
  SetNoOfDecimalPlaces - number of decimal places WriteReal and
                        WriteLongReal should emit. This procedure
                        can be used to override the default
                        DefaultDecimalPlaces constant.
*)

PROCEDURE SetNoOfDecimalPlaces (places: CARDINAL) ;

(*
  ReadReal - reads a real number, legal syntaxes include:
              100, 100.0, 100e0, 100E0, 100E-1, E2, +1E+2, 1e+2
*)

PROCEDURE ReadReal (VAR x: REAL) ;

(*
  WriteReal - writes a real to the terminal. The real number
              is right justified and, n, is the minimum field
              width.
*)

PROCEDURE WriteReal (x: REAL; n: CARDINAL) ;

(*
  WriteRealOct - writes the real to terminal in octal words.
*)

```

```
PROCEDURE WriteRealOct (x: REAL) ;

(*
  ReadLongReal - reads a LONGREAL number, legal syntaxes include:
                  100, 100.0, 100e0, 100E0, 100E-1, E2, +1E+2, 1e+2
*)

PROCEDURE ReadLongReal (VAR x: LONGREAL) ;

(*
  WriteLongReal - writes a LONGREAL to the terminal. The real number
                  is right justified and, n, is the minimum field
                  width.
*)

PROCEDURE WriteLongReal (x: LONGREAL; n: CARDINAL) ;

(*
  WriteLongRealOct - writes the LONGREAL to terminal in octal words.
*)

PROCEDURE WriteLongRealOct (x: LONGREAL) ;

(*
  ReadShortReal - reads a SHORTREAL number, legal syntaxes include:
                  100, 100.0, 100e0, 100E0, 100E-1, E2, +1E+2, 1e+2
*)

PROCEDURE ReadShortReal (VAR x: SHORTREAL) ;

(*
  WriteShortReal - writes a SHORTREAL to the terminal. The real number
                  is right justified and, n, is the minimum field
                  width.
*)

PROCEDURE WriteShortReal (x: SHORTREAL; n: CARDINAL) ;

(*
  WriteShortRealOct - writes the SHORTREAL to terminal in octal words.
```

\*)

```
PROCEDURE WriteShortRealOct (x: SHORTREAL) ;
```

```
END RealInOut.
```



```
        and places the result into, dest.
*)

PROCEDURE ConCat (s1, s2: ARRAY OF CHAR; VAR dest: ARRAY OF CHAR) ;

(*
  Length - return the length of string, s.
*)

PROCEDURE Length (s: ARRAY OF CHAR) : CARDINAL ;

(*
  CompareStr - compare two strings, left, and, right.
*)

PROCEDURE CompareStr (left, right: ARRAY OF CHAR) : INTEGER ;

END Strings.
```

### 4.2.23 gm2-libs-log/Termbase

```
DEFINITION MODULE Termbase ;
```

```
(*
  Initially the read routines from Keyboard and the
  write routine from Display is assigned to the Read,
  KeyPressed and Write procedures.
*)
```

```
EXPORT QUALIFIED ReadProcedure, StatusProcedure, WriteProcedure,
                  AssignRead, AssignWrite, UnAssignRead, UnAssignWrite,
                  Read, KeyPressed, Write ;
```

```
TYPE
```

```
  ReadProcedure = PROCEDURE (VAR CHAR) ;
  WriteProcedure = PROCEDURE (CHAR) ;
  StatusProcedure = PROCEDURE () : BOOLEAN ;
```

```
(*
  AssignRead - assigns a read procedure and status procedure for terminal
  input. Done is set to TRUE if successful. Subsequent
  Read and KeyPressed calls are mapped onto the user supplied
  procedures. The previous read and status procedures are
  uncovered and reused after UnAssignRead is called.
*)
```

```
PROCEDURE AssignRead (rp: ReadProcedure; sp: StatusProcedure;
                     VAR Done: BOOLEAN) ;
```

```
(*
  UnAssignRead - undo the last call to AssignRead and set Done to TRUE
  on success.
*)
```

```
PROCEDURE UnAssignRead (VAR Done: BOOLEAN) ;
```

```
(*
  Read - reads a single character using the currently active read
  procedure.
*)
```

```
PROCEDURE Read (VAR ch: CHAR) ;
```

```
(*
  KeyPressed - returns TRUE if a character is available to be read.
*)
```

```
PROCEDURE KeyPressed () : BOOLEAN ;
```

```
(*
  AssignWrite - assigns a write procedure for terminal output.
                Done is set to TRUE if successful. Subsequent
                Write calls are mapped onto the user supplied
                procedure. The previous write procedure is
                uncovered and reused after UnAssignWrite is called.
*)
```

```
PROCEDURE AssignWrite (wp: WriteProcedure; VAR Done: BOOLEAN) ;
```

```
(*
  UnAssignWrite - undo the last call to AssignWrite and set Done to TRUE
                  on success.
*)
```

```
PROCEDURE UnAssignWrite (VAR Done: BOOLEAN) ;
```

```
(*
  Write - writes a single character using the currently active write
          procedure.
*)
```

```
PROCEDURE Write (VAR ch: CHAR) ;
```

```
END Termbase.
```



```
PROCEDURE Write (ch: CHAR) ;

(*
  WriteString - writes out a string which is terminated by a <nul>
                character or the end of string HIGH(s).
*)

PROCEDURE WriteString (s: ARRAY OF CHAR) ;

(*
  WriteLn - writes a lf character.
*)

PROCEDURE WriteLn ;

END Terminal.
```

## 4.2.25 gm2-libs-log/TimeDate

```

DEFINITION MODULE TimeDate ;

(*
  Legacy compatibility - you are advised to use cleaner
  designed modules based on 'man 3 strtime'
  and friends for new projects as the day value here is ugly.
  [it was mapped onto MSDOS pre 2000].
*)

EXPORT QUALIFIED Time, GetTime, SetTime, CompareTime, TimeToZero,
                  TimeToString ;

TYPE
(*
  day holds:  bits 0..4 = day of month (1..31)
               5..8 = month of year (1..12)
               9..  = year - 1900
  minute holds:  hours * 60 + minutes
  millisec holds: seconds * 1000 + millisec
                  which is reset to 0 every minute
*)

  Time = RECORD
    day, minute, millisec: CARDINAL ;
  END ;

(*
  GetTime - returns the current date and time.
*)

PROCEDURE GetTime (VAR curTime: Time) ;

(*
  SetTime - does nothing, but provides compatibility with
            the Logitech-3.0 library.
*)

PROCEDURE SetTime (curTime: Time) ;

(*
  CompareTime - compare two dates and time which returns:

```

```
        -1  if t1 < t2
         0  if t1 = t2
         1  if t1 > t2
*)

PROCEDURE CompareTime (t1, t2: Time) : INTEGER ;

(*
  TimeToZero - initializes, t, to zero.
*)

PROCEDURE TimeToZero (VAR t: Time) ;

(*
  TimeToString - convert time, t, to a string.
                 The string, s, should be at least 19 characters
                 long and the returned string will be

                 yyyy-mm-dd hh:mm:ss
*)

PROCEDURE TimeToString (t: Time; VAR s: ARRAY OF CHAR) ;

END TimeDate.
```

### 4.3 PIM coroutine support

This directory contains a PIM SYSTEM containing the PROCESS primitives built on top of gthreads.

#### 4.3.1 gm2-libs-coroutines/Executive

```

DEFINITION MODULE Executive ;

EXPORT QUALIFIED SEMAPHORE, DESCRIPTOR,
    InitProcess, KillProcess, Resume, Suspend, InitSemaphore,
    Wait, Signal, WaitForIO, Ps, GetCurrentProcess,
    RotateRunQueue, ProcessName, DebugProcess ;

TYPE
    SEMAPHORE ;          (* defines Dijkstras semaphores *)
    DESCRIPTOR ;         (* handle onto a process *)

(*
    InitProcess - initializes a process which is held in the suspended
                  state. When the process is resumed it will start executing
                  procedure, p. The process has a maximum stack size of,
                  StackSize, bytes and its textual name is, Name.
                  The StackSize should be at least 5000 bytes.
*)

PROCEDURE InitProcess (p: PROC; StackSize: CARDINAL;
                      Name: ARRAY OF CHAR) : DESCRIPTOR ;

(*
    KillProcess - kills the current process. Notice that if InitProcess
                  is called again, it might reuse the DESCRIPTOR of the
                  killed process. It is the responsibility of the caller
                  to ensure all other processes understand this process
                  is different.
*)

PROCEDURE KillProcess ;

(*
    Resume - resumes a suspended process. If all is successful then the process, p,
             is returned. If it fails then NIL is returned.
*)

PROCEDURE Resume (d: DESCRIPTOR) : DESCRIPTOR ;

```

```
(*
  Suspend - suspend the calling process.
            The process can only continue running if another process
            Resumes it.
*)

PROCEDURE Suspend ;

(*
  InitSemaphore - creates a semaphore whose initial value is, v, and
                 whose name is, Name.
*)

PROCEDURE InitSemaphore (v: CARDINAL; Name: ARRAY OF CHAR) : SEMAPHORE ;

(*
  Wait - performs dijkstras P operation on a semaphore.
        A process which calls this procedure will
        wait until the value of the semaphore is > 0
        and then it will decrement this value.
*)

PROCEDURE Wait (s: SEMAPHORE) ;

(*
  Signal - performs dijkstras V operation on a semaphore.
          A process which calls the procedure will increment
          the semaphores value.
*)

PROCEDURE Signal (s: SEMAPHORE) ;

(*
  WaitForIO - waits for an interrupt to occur on vector, VectorNo.
*)

PROCEDURE WaitForIO (VectorNo: CARDINAL) ;

(*
  Ps - displays a process list together with process status.
```

```
*)

PROCEDURE Ps ;

(*
    GetCurrentProcess - returns the descriptor of the current running
                      process.
*)

PROCEDURE GetCurrentProcess () : DESCRIPTOR ;

(*
    RotateRunQueue - rotates the process run queue.
                   It does not call the scheduler.
*)

PROCEDURE RotateRunQueue ;

(*
    ProcessName - displays the name of process, d, through
                 DebugString.
*)

PROCEDURE ProcessName (d: DESCRIPTOR) ;

(*
    DebugProcess - gdb debug handle to enable users to debug deadlocked
                  semaphore processes.
*)

PROCEDURE DebugProcess (d: DESCRIPTOR) ;

END Executive.
```

### 4.3.2 gm2-libs-coroutines/KeyBoardLEDs

```
DEFINITION MODULE KeyBoardLEDs ;

EXPORT QUALIFIED SwitchLeds,
                  SwitchScroll, SwitchNum, SwitchCaps ;

(*
  SwitchLeds - switch the keyboard LEDs to the state defined
               by the BOOLEAN variables. TRUE = ON.
*)

PROCEDURE SwitchLeds (NumLock, CapsLock, ScrollLock: BOOLEAN) ;

(*
  SwitchScroll - switches the scroll LED on or off.
*)

PROCEDURE SwitchScroll (Scroll: BOOLEAN) ;

(*
  SwitchNum - switches the Num LED on or off.
*)

PROCEDURE SwitchNum (Num: BOOLEAN) ;

(*
  SwitchCaps - switches the Caps LED on or off.
*)

PROCEDURE SwitchCaps (Caps: BOOLEAN) ;

END KeyBoardLEDs.
```

### 4.3.3 gm2-libs-coroutines/SYSTEM

```

DEFINITION MODULE SYSTEM ;

(* This module is designed to be used on a native operating system
   rather than an embedded system as it implements the coroutine
   primitives TRANSFER, IOTRANSFER and
   NEWPROCESS through the GNU Pthread library.  *)

FROM COROUTINES IMPORT PROTECTION ;

EXPORT QUALIFIED (* the following are built into the compiler: *)
  ADDRESS, WORD, BYTE, CSIZE_T, CSSIZE_T, COFF_T, (*
  Target specific data types. *)
  ADR, TSIZE, ROTATE, SHIFT, THROW, TBITSIZE,
  (* SIZE is exported depending upon -fpim2 and
     -fpedantic.  *)
  (* The rest are implemented in SYSTEM.mod.  *)
  PROCESS, TRANSFER, NEWPROCESS, IOTRANSFER,
  LISTEN,
  ListenLoop, TurnInterrupts,
  (* Internal GM2 compiler functions.  *)
  ShiftVal, ShiftLeft, ShiftRight,
  RotateVal, RotateLeft, RotateRight ;

TYPE
  PROCESS = RECORD
    context: INTEGER ;
  END ;

(* Note that the full list of system and sized datatypes include:
   LOC, WORD, BYTE, ADDRESS,

   (and the non language standard target types)

   INTEGER8, INTEGER16, INTEGER32, INTEGER64,
   CARDINAL8, CARDINAL16, CARDINAL32, CARDINAL64,
   WORD16, WORD32, WORD64, BITSET8, BITSET16,
   BITSET32, REAL32, REAL64, REAL128, COMPLEX32,
   COMPLEX64, COMPLEX128, CSIZE_T, CSSIZE_T.

   Also note that the non-standard data types will
   move into another module in the future.  *)

(* The following types are supported on this target:
   (* Target specific data types.  *)

```

\*)

(\*

TRANSFER - save the current volatile environment into, p1.  
Restore the volatile environment from, p2.

\*)

PROCEDURE TRANSFER (VAR p1: PROCESS; p2: PROCESS) ;

(\*

NEWPROCESS - p is a parameterless procedure, a, is the origin of  
the workspace used for the process stack and containing  
the volatile environment of the process. StackSize, is  
the maximum size of the stack in bytes which can be used  
by this process. new, is the new process.

\*)

PROCEDURE NEWPROCESS (p: PROC; a: ADDRESS; StackSize: CARDINAL; VAR new: PROCESS) ;■

(\*

IOTRANSFER - saves the current volatile environment into, First,  
and restores volatile environment, Second.  
When an interrupt, InterruptNo, is encountered then  
the reverse takes place. (The then current volatile  
environment is shelved onto Second and First is resumed).■

NOTE: that upon interrupt the Second might not be the  
same process as that before the original call to  
IOTRANSFER.

\*)

PROCEDURE IOTRANSFER (VAR First, Second: PROCESS; InterruptNo: CARDINAL) ;■

(\*

LISTEN - briefly listen for any interrupts.

\*)

PROCEDURE LISTEN ;

(\*

ListenLoop - should be called instead of users writing:

```

LOOP
    LISTEN
END

```

It performs the same function but yields control back to the underlying operating system via a call to pth\_select. It also checks for deadlock. This function returns when an interrupt occurs ie a file descriptor becomes ready or a time event expires. See the module RTint.

```
*)
```

```
PROCEDURE ListenLoop ;
```

```

(*)
    TurnInterrupts - switches processor interrupts to the protection
                    level, to. It returns the old value.
*)

```

```
PROCEDURE TurnInterrupts (to: PROTECTION) : PROTECTION ;
```

```

(*)
    all the functions below are declared internally to gm2
    =====

```

```

PROCEDURE ADR (VAR v: <anytype>): ADDRESS;
    (* Returns the address of variable v. *)

```

```

PROCEDURE SIZE (v: <type>) : ZType;
    (* Returns the number of BYTES used to store a v of
       any specified <type>. Only available if -fpim2 is used.
    *)

```

```

PROCEDURE TSIZE (<type>) : CARDINAL;
    (* Returns the number of BYTES used to store a value of the
       specified <type>.
    *)

```

```

PROCEDURE ROTATE (val: <a set type>;
                  num: INTEGER): <type of first parameter>;
    (* Returns a bit sequence obtained from val by rotating up or down
       (left or right) by the absolute value of num. The direction is
       down if the sign of num is negative, otherwise the direction is up.
    *)

```

```

PROCEDURE SHIFT (val: <a set type>;
                 num: INTEGER): <type of first parameter>;
(* Returns a bit sequence obtained from val by shifting up or down
   (left or right) by the absolute value of num, introducing
   zeros as necessary. The direction is down if the sign of
   num is negative, otherwise the direction is up.
*)

PROCEDURE THROW (i: INTEGER) <* noreturn *> ;
(*
   THROW is a GNU extension and was not part of the PIM or ISO
   standards. It throws an exception which will be caught by the EXCEPT
   block (assuming it exists). This is a compiler builtin function which
   interfaces to the GCC exception handling runtime system.
   GCC uses the term throw, hence the naming distinction between
   the GCC builtin and the Modula-2 runtime library procedure Raise.
   The later library procedure Raise will call SYSTEM.THROW after
   performing various housekeeping activities.
*)

PROCEDURE TBITSIZE (<type>) : CARDINAL ;
(* Returns the minimum number of bits necessary to represent
   <type>. This procedure function is only useful for determining
   the number of bits used for any type field within a packed RECORD.
   It is not particularly useful elsewhere since <type> might be
   optimized for speed, for example a BOOLEAN could occupy a WORD.
*)

(* The following procedures are invoked by GNU Modula-2 to
   shift non word sized set types. They are not strictly part
   of the core PIM Modula-2, however they are used
   to implement the SHIFT procedure defined above,
   which are in turn used by the Logitech compatible libraries.

   Users will access these procedures by using the procedure
   SHIFT above and GNU Modula-2 will map SHIFT onto one of
   the following procedures.

   ShiftVal - is a runtime procedure whose job is to implement
               the SHIFT procedure of ISO SYSTEM. GNU Modula-2 will
               inline a SHIFT of a single WORD sized set and will
               only call this routine for larger sets.
*)

```

```
PROCEDURE ShiftVal (VAR s, d: ARRAY OF BITSET;
                   SetSizeInBits: CARDINAL;
                   ShiftCount: INTEGER) ;

(*
  ShiftLeft - performs the shift left for a multi word set.
              This procedure might be called by the back end of
              GNU Modula-2 depending whether amount is known at
              compile time.
*)

PROCEDURE ShiftLeft (VAR s, d: ARRAY OF BITSET;
                    SetSizeInBits: CARDINAL;
                    ShiftCount: CARDINAL) ;

(*
  ShiftRight - performs the shift left for a multi word set.
               This procedure might be called by the back end of
               GNU Modula-2 depending whether amount is known at
               compile time.
*)

PROCEDURE ShiftRight (VAR s, d: ARRAY OF BITSET;
                     SetSizeInBits: CARDINAL;
                     ShiftCount: CARDINAL) ;

(*
  RotateVal - is a runtime procedure whose job is to implement
              the ROTATE procedure of ISO SYSTEM. GNU Modula-2 will
              inline a ROTATE of a single WORD (or less)
              sized set and will only call this routine for
              larger sets.
*)

PROCEDURE RotateVal (VAR s, d: ARRAY OF BITSET;
                    SetSizeInBits: CARDINAL;
                    RotateCount: INTEGER) ;

(*
  RotateLeft - performs the rotate left for a multi word set.
               This procedure might be called by the back end of
               GNU Modula-2 depending whether amount is known
               at compile time.
```

\*)

```
PROCEDURE RotateLeft (VAR s, d: ARRAY OF BITSET;  
                      SetSizeInBits: CARDINAL;  
                      RotateCount: CARDINAL) ;
```

(\*

RotateRight - performs the rotate right for a multi word set.  
This procedure might be called by the back end of  
GNU Modula-2 depending whether amount is known at  
compile time.

\*)

```
PROCEDURE RotateRight (VAR s, d: ARRAY OF BITSET;  
                      SetSizeInBits: CARDINAL;  
                      RotateCount: CARDINAL) ;
```

END SYSTEM.

#### 4.3.4 gm2-libs-coroutines/TimerHandler

```

DEFINITION MODULE TimerHandler ;

(* It also provides the Executive with a basic round robin scheduler. *)

EXPORT QUALIFIED TicksPerSecond, GetTicks,
                  EVENT,
                  Sleep, ArmEvent, WaitOn, Cancel, ReArmEvent ;

CONST
  TicksPerSecond = 25 ; (* Number of ticks per second. *)

TYPE
  EVENT ;

(*
  GetTicks - returns the number of ticks since boottime.
*)

PROCEDURE GetTicks () : CARDINAL ;

(*
  Sleep - suspends the current process for a time, t.
          The time is measured in ticks.
*)

PROCEDURE Sleep (t: CARDINAL) ;

(*
  ArmEvent - initializes an event, e, to occur at time, t.
             The time, t, is measured in ticks.
             The event is NOT placed onto the event queue.
*)

PROCEDURE ArmEvent (t: CARDINAL) : EVENT ;

(*
  WaitOn - places event, e, onto the event queue and then the calling
           process suspends. It is resumed up by either the event
           expiring or the event, e, being cancelled.
           TRUE is returned if the event was cancelled
*)

```

```
FALSE is returned if the event expires.
The event, e, is always assigned to NIL when the function
finishes.

*)

PROCEDURE WaitOn (VAR e: EVENT) : BOOLEAN ;

(*
  Cancel - cancels the event, e, on the event queue and makes
           the appropriate process runnable again.
  TRUE is returned if the event was cancelled and
  FALSE is returned if the event was not found or
           no process was waiting on this event.
*)

PROCEDURE Cancel (e: EVENT) : BOOLEAN ;

(*
  ReArmEvent - removes an event, e, from the event queue. A new time
               is given to this event and it is then re-inserted onto the
               event queue in the correct place.
  TRUE is returned if this occurred
  FALSE is returned if the event was not found.
*)

PROCEDURE ReArmEvent (e: EVENT; t: CARDINAL) : BOOLEAN ;

END TimerHandler.
```



### 4.4.1 gm2-libs-iso/COROUTINES

```

DEFINITION MODULE COROUTINES;

(* Facilities for coroutines and the handling of interrupts *)

IMPORT SYSTEM ;

CONST
    UnassignedPriority = 0 ;

TYPE
    COROUTINE ; (* Values of this type are created dynamically by NEWCOROUTINE
                  and identify the coroutine in subsequent operations *)
    INTERRUPTSOURCE = CARDINAL ;
    PROTECTION = [UnassignedPriority..7] ;

PROCEDURE NEWCOROUTINE (procBody: PROC;
                        workspace: SYSTEM.ADDRESS;
                        size: CARDINAL;
                        VAR cr: COROUTINE;
                        [initProtection: PROTECTION = UnassignedPriority]);
(* Creates a new coroutine whose body is given by procBody, and
   returns the identity of the coroutine in cr. workspace is a
   pointer to the work space allocated to the coroutine; size
   specifies the size of this workspace in terms of SYSTEM.LOC.

   The optarg, initProtection, may contain a single parameter which
   specifies the initial protection level of the coroutine.
*)

PROCEDURE TRANSFER (VAR from: COROUTINE; to: COROUTINE);
(* Returns the identity of the calling coroutine in from, and
   transfers control to the coroutine specified by to.
*)

PROCEDURE IOTRANSFER (VAR from: COROUTINE; to: COROUTINE);
(* Returns the identity of the calling coroutine in from and
   transfers control to the coroutine specified by to. On
   occurrence of an interrupt, associated with the caller, control
   is transferred back to the caller, and the identity of the
   interrupted coroutine is returned in from. The calling coroutine
   must be associated with a source of interrupts.
*)

```



It also checks for deadlock.

Note that this function does return when an interrupt occurs.■

(File descriptor becomes ready or time event expires).

\*)

PROCEDURE ListenLoop ;

END COROUTINES.



```
                                are not supported in combination *)
alreadyOpen,                  (* the source/destination is already open for operations not su
                                in combination with the requested operations *)■
otherProblem                  (* open failed for some other reason *)
);

END ChanConsts.
```













#### 4.4.8 gm2-libs-iso/ConvStringShort

```

DEFINITION MODULE ConvStringShort ;

FROM DynamicStrings IMPORT String ;

(*
  RealToFloatString - converts a real with, sigFigs, into a string
                    and returns the result as a string.
*)

PROCEDURE RealToFloatString (real: SHORTREAL; sigFigs: CARDINAL) : String ;■

(*
  RealToEngString - converts the value of real to floating-point
                  string form, with sigFigs significant figures.
                  The number is scaled with one to three digits
                  in the whole number part and with an exponent
                  that is a multiple of three.
*)

PROCEDURE RealToEngString (real: SHORTREAL; sigFigs: CARDINAL) : String ;■

(*
  RealToFixedString - returns the number of characters in the fixed-point
                   string representation of real rounded to the given
                   place relative to the decimal point.
*)

PROCEDURE RealToFixedString (real: SHORTREAL; place: INTEGER) : String ;

END ConvStringShort.

```

#### 4.4.9 gm2-libs-iso/ConvTypes

```
DEFINITION MODULE ConvTypes;
```

```
  (* Common types used in the string conversion modules *)
```

```
TYPE
```

```
  ConvResults =      (* Values of this type are used to express the format of a string
  (
    strAllRight,      (* the string format is correct for the corresponding conversion *)
    strOutOfRange,   (* the string is well-formed but the value cannot be represented *)
    strWrongFormat,   (* the string is in the wrong format for the conversion *)
    strEmpty          (* the given string is empty *)
  );
```

```
  ScanClass = (* Values of this type are used to classify input to finite state scanner
  (
    padding, (* a leading or padding character at this point in the scan - ignore it *)
    valid,   (* a valid character at this point in the scan - accept it *)
    invalid, (* an invalid character at this point in the scan - reject it *)
    terminator (* a terminating character at this point in the scan (not part of token)
  );
```

```
  ScanState = (* The type of lexical scanning control procedures *)
    PROCEDURE (CHAR, VAR ScanClass, VAR ScanState);
```

```
END ConvTypes.
```

#### 4.4.10 gm2-libs-iso/EXCEPTIONS

```
DEFINITION MODULE EXCEPTIONS;

(* Provides facilities for raising user exceptions
   and for making enquiries concerning the current execution state.
*)

TYPE
  ExceptionSource;    (* values of this type are used within library
                       modules to identify the source of raised
                       exceptions *)
  ExceptionNumber = CARDINAL;

PROCEDURE AllocateSource(VAR newSource: ExceptionSource);
  (* Allocates a unique value of type ExceptionSource *)

PROCEDURE RAISE (source: ExceptionSource;
                 number: ExceptionNumber; message: ARRAY OF CHAR)
  <* noreturn *> ;
  (* Associates the given values of source, number and message with
     the current context and raises an exception.
  *)

PROCEDURE CurrentNumber (source: ExceptionSource): ExceptionNumber;
  (* If the current coroutine is in the exceptional execution state
     because of the raising of an exception from source, returns
     the corresponding number, and otherwise raises an exception.
  *)

PROCEDURE GetMessage (VAR text: ARRAY OF CHAR);
  (* If the current coroutine is in the exceptional execution state,
     returns the possibly truncated string associated with the
     current context. Otherwise, in normal execution state,
     returns the empty string.
  *)

PROCEDURE IsCurrentSource (source: ExceptionSource): BOOLEAN;
  (* If the current coroutine is in the exceptional execution state
     because of the raising of an exception from source, returns
     TRUE, and otherwise returns FALSE.
  *)

PROCEDURE IsExceptionalExecution (): BOOLEAN;
  (* If the current coroutine is in the exceptional execution state
     because of the raising of an exception, returns TRUE, and
     otherwise returns FALSE.
```

\*)

END EXCEPTIONS.

#### 4.4.11 gm2-libs-iso/ErrnoCategory

```
DEFINITION MODULE ErrnoCategory ;
```

```
(*
  provides an interface to errno (if the system
  supports it) which determines whether the current
  errno is a hard or soft error.  These distinctions
  are needed by the ISO Modula-2 libraries.  Not all
  errno values are tested, only those which could be
  related to a device.
*)
```

```
IMPORT ChanConsts ;
```

```
(*
  IsErrnoHard - returns TRUE if the value of errno is associated with
                  a hard device error.
*)
```

```
PROCEDURE IsErrnoHard (e: INTEGER) : BOOLEAN ;
```

```
(*
  IsErrnoSoft - returns TRUE if the value of errno is associated with
                  a soft device error.
*)
```

```
PROCEDURE IsErrnoSoft (e: INTEGER) : BOOLEAN ;
```

```
(*
  UnAvailable - returns TRUE if the value of errno indicates that
                  the resource or device is unavailable for some
                  reason.
*)
```

```
PROCEDURE UnAvailable (e: INTEGER) : BOOLEAN ;
```

```
(*
  GetOpenResults - maps errno onto the ISO Modula-2 enumerated
                  type, OpenResults.
*)
```

```
PROCEDURE GetOpenResults (e: INTEGER) : ChanConsts.OpenResults ;
```











```
        execution state because of the raising of an exception from
        ChanExceptions; otherwise returns FALSE.
    *)

PROCEDURE ChanException (): ChanExceptions;
    (* If the current coroutine is in the exceptional execution state
       because of the raising of an exception from ChanExceptions,
       returns the corresponding enumeration value, and otherwise
       raises an exception.
    *)

    (* When a device procedure detects a device error, it raises the
       exception softDeviceError or hardDeviceError. If these
       exceptions are handled, the following facilities may be
       used to discover an implementation-defined error number for
       the channel.
    *)

TYPE
    DeviceErrNum = INTEGER;

PROCEDURE DeviceError (cid: ChanId): DeviceErrNum;
    (* If a device error exception has been raised for the channel cid,
       returns the error number stored by the device module.
    *)

END IOChan.
```

#### 4.4.14 gm2-libs-iso/IOConsts

```
DEFINITION MODULE IOConsts;
```

```
    (* Types and constants for input/output modules *)
```

```
TYPE
```

```
    ReadResults = (* This type is used to classify the result of an input operation *)
```

```
    (
```

```
        notKnown,      (* no read result is set *)
```

```
        allRight,      (* data is as expected or as required *)
```

```
        outOfRange,    (* data cannot be represented *)
```

```
        wrongFormat,   (* data not in expected format *)
```

```
        endOfLine,     (* end of line seen before expected data *)
```

```
        endOfInput     (* end of input seen before expected data *)
```

```
    );
```

```
END IOConsts.
```



```

FlushProc      = PROCEDURE (DeviceTablePtr) ;
FreeProc       = PROCEDURE (DeviceTablePtr) ;
    (* Carry out the operations involved in closing the corresponding
       channel, including flushing buffers, but do not unmake the
       channel.
    *)

TYPE
    DeviceData = SYSTEM.ADDRESS;

    DeviceTable =
        RECORD
            (* Initialized by MakeChan to: *)
            cd: DeviceData;          (* the value NIL *)
            did: DeviceId;           (* the value given in the call of MakeChan *)
            cid: IOChan.ChanId;      (* the identity of the channel *)
            result: IOConsts.ReadResults; (* the value notKnown *)
            errNum: IOChan.DeviceErrNum; (* undefined *)
            flags: ChanConsts.FlagSet; (* ChanConsts.FlagSet{} *)
            doLook: LookProc;         (* raise exception notAvailable *)
            doSkip: SkipProc;         (* raise exception notAvailable *)
            doSkipLook: SkipLookProc; (* raise exception notAvailable *)
            doLnWrite: WriteLnProc;   (* raise exception notAvailable *)
            doTextRead: TextReadProc; (* raise exception notAvailable *)
            doTextWrite: TextWriteProc; (* raise exception notAvailable *)
            doRawRead: RawReadProc;   (* raise exception notAvailable *)
            doRawWrite: RawWriteProc; (* raise exception notAvailable *)
            doGetName: GetNameProc;   (* return the empty string *)
            doReset: ResetProc;       (* do nothing *)
            doFlush: FlushProc;       (* do nothing *)
            doFree: FreeProc;         (* do nothing *)
        END;

    (* The pointer to the device table for a channel is obtained using the
       following procedure: *)

    (*
       If the device module identified by did is not the module that made
       the channel identified by cid, the exception wrongDevice is raised.
    *)

    PROCEDURE DeviceTablePtrValue (cid: IOChan.ChanId; did: DeviceId): DeviceTablePtr;

    (*
       Tests if the device module identified by did is the module

```

```

        that made the channel identified by cid.
    *)

PROCEDURE IsDevice (cid: IOChan.ChanId; did: DeviceId) : BOOLEAN;

TYPE
    DevExceptionRange = IOChan.ChanExceptions;

    (*
        ISO standard states defines

        DevExceptionRange = [IOChan.notAvailable .. IOChan.textParseError];

        however this must be a bug as other modules need to raise
        IOChan.wrongDevice exceptions.
    *)

PROCEDURE RAISEdevException (cid: IOChan.ChanId; did: DeviceId;
                             x: DevExceptionRange; s: ARRAY OF CHAR) <* noreturn *> ;

    (* If the device module identified by did is not the module that made the channel
       identified by cid, the exception wrongDevice is raised; otherwise the given excep
       is raised, and the string value in s is included in the exception message.
    *)

PROCEDURE IsIOException () : BOOLEAN;

    (* Returns TRUE if the current coroutine is in the exceptional execution state
       because of the raising af an exception from ChanExceptions;
       otherwise FALSE.
    *)

PROCEDURE IOException () : IOChan.ChanExceptions;

    (* If the current coroutine is in the exceptional execution state because of the
       raising af an exception from ChanExceptions, returns the corresponding
       enumeration value, and otherwise raises an exception.
    *)

END IOLink.
```

#### 4.4.16 gm2-libs-iso/IOResult

```
DEFINITION MODULE IOResult;
```

```
    (* Read results for specified channels *)
```

```
IMPORT IOConsts, IOChan;
```

```
TYPE
```

```
    ReadResults = IOConsts.ReadResults;
```

```
    (*
```

```
    ReadResults = (* This type is used to classify the result of an input operation *
```

```
    (
```

```
        notKnown,      (* no read result is set *)
```

```
        allRight,      (* data is as expected or as required *)
```

```
        outOfRange,    (* data cannot be represented *)
```

```
        wrongFormat,   (* data not in expected format *)
```

```
        endOfLine,     (* end of line seen before expected data *)
```

```
        endOfInput     (* end of input seen before expected data *)
```

```
    );
```

```
    *)
```

```
PROCEDURE ReadResult (cid: IOChan.ChanId): ReadResults;
```

```
    (* Returns the result for the last read operation on the channel cid. *)■
```

```
END IOResult.
```

#### 4.4.17 gm2-libs-iso/LongComplexMath

```

DEFINITION MODULE LongComplexMath;

  (* Mathematical functions for the type LONGCOMPLEX *)

CONST
  i =      CMPLX (0.0, 1.0);
  one =    CMPLX (1.0, 0.0);
  zero =   CMPLX (0.0, 0.0);

PROCEDURE abs (z: LONGCOMPLEX): LONGREAL;
  (* Returns the length of z *)

PROCEDURE arg (z: LONGCOMPLEX): LONGREAL;
  (* Returns the angle that z subtends to the positive real axis *)

PROCEDURE conj (z: LONGCOMPLEX): LONGCOMPLEX;
  (* Returns the complex conjugate of z *)

PROCEDURE power (base: LONGCOMPLEX; exponent: LONGREAL): LONGCOMPLEX;
  (* Returns the value of the number base raised to the power exponent *)

PROCEDURE sqrt (z: LONGCOMPLEX): LONGCOMPLEX;
  (* Returns the principal square root of z *)

PROCEDURE exp (z: LONGCOMPLEX): LONGCOMPLEX;
  (* Returns the complex exponential of z *)

PROCEDURE ln (z: LONGCOMPLEX): LONGCOMPLEX;
  (* Returns the principal value of the natural logarithm of z *)

PROCEDURE sin (z: LONGCOMPLEX): LONGCOMPLEX;
  (* Returns the sine of z *)

PROCEDURE cos (z: LONGCOMPLEX): LONGCOMPLEX;
  (* Returns the cosine of z *)

PROCEDURE tan (z: LONGCOMPLEX): LONGCOMPLEX;
  (* Returns the tangent of z *)

PROCEDURE arcsin (z: LONGCOMPLEX): LONGCOMPLEX;
  (* Returns the arcsine of z *)

PROCEDURE arccos (z: LONGCOMPLEX): LONGCOMPLEX;
  (* Returns the arccosine of z *)

```

```
PROCEDURE arctan (z: LONGCOMPLEX): LONGCOMPLEX;
    (* Returns the arctangent of z *)

PROCEDURE polarToComplex (abs, arg: LONGREAL): LONGCOMPLEX;
    (* Returns the complex number with the specified polar coordinates *)

PROCEDURE scalarMult (scalar: LONGREAL; z: LONGCOMPLEX): LONGCOMPLEX;
    (* Returns the scalar product of scalar with z *)

PROCEDURE IsCMathException (): BOOLEAN;
    (* Returns TRUE if the current coroutine is in the exceptional execution state
       because of the raising of an exception in a routine from this module; otherwise
       returns FALSE.
    *)

END LongComplexMath.
```

#### 4.4.18 gm2-libs-iso/LongConv

```

DEFINITION MODULE LongConv;

    (* Low-level LONGREAL/string conversions *)

IMPORT
    ConvTypes;

TYPE
    ConvResults = ConvTypes.ConvResults; (* strAllRight, strOutOfRange,
                                           strWrongFormat, strEmpty *)

PROCEDURE ScanReal (inputCh: CHAR; VAR chClass: ConvTypes.ScanClass;
                   VAR nextState: ConvTypes.ScanState);
    (* Represents the start state of a finite state scanner for real
       numbers - assigns class of inputCh to chClass and a procedure
       representing the next state to nextState.
    *)

PROCEDURE FormatReal (str: ARRAY OF CHAR): ConvResults;
    (* Returns the format of the string value for conversion to LONGREAL. *)

PROCEDURE ValueReal (str: ARRAY OF CHAR): LONGREAL;
    (* Returns the value corresponding to the real number string value
       str if str is well-formed; otherwise raises the LongConv exception.
    *)

PROCEDURE LengthFloatReal (real: LONGREAL; sigFigs: CARDINAL): CARDINAL;
    (* Returns the number of characters in the floating-point string
       representation of real with sigFigs significant figures.
    *)

PROCEDURE LengthEngReal (real: LONGREAL; sigFigs: CARDINAL): CARDINAL;
    (* Returns the number of characters in the floating-point engineering
       string representation of real with sigFigs significant figures.
    *)

PROCEDURE LengthFixedReal (real: LONGREAL; place: INTEGER): CARDINAL;
    (* Returns the number of characters in the fixed-point string
       representation of real rounded to the given place relative to the
       decimal point.
    *)

PROCEDURE IsRConvException (): BOOLEAN;
    (* Returns TRUE if the current coroutine is in the exceptional
       execution state because of the raising of an exception in a

```

```
        routine from this module; otherwise returns FALSE.  
*)  
  
END LongConv.
```



```
*)  
  
PROCEDURE WriteReal (cid: IOChan.ChanId; real: LONGREAL;  
                    width: CARDINAL);  
  (* Writes the value of real to cid, as WriteFixed if the  
    sign and magnitude can be shown in the given width, or  
    otherwise as WriteFloat. The number of places or  
    significant digits depends on the given width.  
  *)  
  
END LongIO.
```



```
        execution state because of the raising of an exception in a  
        routine from this module; otherwise returns FALSE.  
*)
```

```
END LongMath.
```

## 4.4.21 gm2-libs-iso/LongStr

```

DEFINITION MODULE LongStr;

  (* LONGREAL/string conversions *)

IMPORT
  ConvTypes;

TYPE
  (* strAllRight, strOutOfRange, strWrongFormat, strEmpty *)
  ConvResults = ConvTypes.ConvResults;

  (* the string form of a signed fixed-point real number is
     ["+" | "-"], decimal digit, {decimal digit}, [".",
     {decimal digit}]
  *)

  (* the string form of a signed floating-point real number is
     signed fixed-point real number, "E", ["+" | "-"],
     decimal digit, {decimal digit}
  *)

PROCEDURE StrToReal (str: ARRAY OF CHAR; VAR real: LONGREAL;
  VAR res: ConvResults);
  (* Ignores any leading spaces in str. If the subsequent characters
     in str are in the format of a signed real number, assigns a
     corresponding value to real. Assigns a value indicating the
     format of str to res.
  *)

PROCEDURE RealToFloat (real: LONGREAL; sigFigs: CARDINAL;
  VAR str: ARRAY OF CHAR);
  (* Converts the value of real to floating-point string form, with
     sigFigs significant figures, and copies the possibly truncated
     result to str.
  *)

PROCEDURE RealToEng (real: LONGREAL; sigFigs: CARDINAL;
  VAR str: ARRAY OF CHAR);
  (* Converts the value of real to floating-point string form, with
     sigFigs significant figures, and copies the possibly truncated
     result to str. The number is scaled with one to three digits
     in the whole number part and with an exponent that is a
     multiple of three.
  *)

```

```
PROCEDURE RealToFixed (real: LONGREAL; place: INTEGER;
                      VAR str: ARRAY OF CHAR);
  (* Converts the value of real to fixed-point string form, rounded
     to the given place relative to the decimal point, and copies
     the possibly truncated result to str.
  *)

PROCEDURE RealToStr (real: LONGREAL; VAR str: ARRAY OF CHAR);
  (* Converts the value of real as RealToFixed if the sign and
     magnitude can be shown within the capacity of str, or
     otherwise as RealToFloat, and copies the possibly truncated
     result to str. The number of places or significant digits
     depend on the capacity of str.
  *)

END LongStr.
```

#### 4.4.22 gm2-libs-iso/LongWholeIO

```

DEFINITION MODULE LongWholeIO;

  (* Input and output of whole numbers in decimal text form
     over specified channels. The read result is of the
     type IOConsts.ReadResults.
  *)

IMPORT IOChan;

  (* The text form of a signed whole number is
     ["+" | "-"], decimal digit, {decimal digit}

     The text form of an unsigned whole number is
     decimal digit, {decimal digit}
  *)

PROCEDURE ReadInt (cid: IOChan.ChanId; VAR int: LONGINT);
  (* Skips leading spaces, and removes any remaining characters
     from cid that form part of a signed whole number. The
     value of this number is assigned to int. The read result
     is set to the value allRight, outOfRange, wrongFormat,
     endOfLine, or endOfInput.
  *)

PROCEDURE WriteInt (cid: IOChan.ChanId; int: LONGINT;
                   width: CARDINAL);
  (* Writes the value of int to cid in text form, in a field of
     the given minimum width. *)

PROCEDURE ReadCard (cid: IOChan.ChanId; VAR card: LONGCARD);
  (* Skips leading spaces, and removes any remaining characters
     from cid that form part of an unsigned whole number. The
     value of this number is assigned to card. The read result
     is set to the value allRight, outOfRange, wrongFormat,
     endOfLine, or endOfInput.
  *)

PROCEDURE WriteCard (cid: IOChan.ChanId; card: LONGCARD;
                   width: CARDINAL);
  (* Writes the value of card to cid in text form, in a field
     of the given minimum width. *)

END LongWholeIO.

```



```
PROCEDURE fractpart (x: LONGREAL): LONGREAL;
  (* Returns the fractional part of x *)

PROCEDURE scale (x: LONGREAL; n: INTEGER): LONGREAL;
  (* Returns the value of x * radix ** n *)

PROCEDURE trunc (x: LONGREAL; n: INTEGER): LONGREAL;
  (* Returns the value of the first n places of x *)

PROCEDURE round (x: LONGREAL; n: INTEGER): LONGREAL;
  (* Returns the value of x rounded to the first n places *)

PROCEDURE synthesize (expart: INTEGER; frapart: LONGREAL): LONGREAL;
  (* Returns a value of the type LONGREAL constructed from the given expart and frapart *)

PROCEDURE setMode (m: Modes);
  (* Sets status flags appropriate to the underlying implementation of the type LONGREAL *)

PROCEDURE currentMode (): Modes;
  (* Returns the current status flags in the form set by setMode *)

PROCEDURE IsLowException (): BOOLEAN;
  (* Returns TRUE if the current coroutine is in the exceptional execution state
     because of the raising of an exception in a routine from this module; otherwise
     returns FALSE.
  *)

END LowLong.
```



```
PROCEDURE fractpart (x: REAL): REAL;
  (* Returns the fractional part of x *)

PROCEDURE scale (x: REAL; n: INTEGER): REAL;
  (* Returns the value of x * radix ** n *)

PROCEDURE trunc (x: REAL; n: INTEGER): REAL;
  (* Returns the value of the first n places of x *)

PROCEDURE round (x: REAL; n: INTEGER): REAL;
  (* Returns the value of x rounded to the first n places *)

PROCEDURE synthesize (expart: INTEGER; frapart: REAL): REAL;
  (* Returns a value of the type REAL constructed from the given expart and frapart *)

PROCEDURE setMode (m: Modes);
  (* Sets status flags appropriate to the underlying implementation of the type REAL *)

PROCEDURE currentMode (): Modes;
  (* Returns the current status flags in the form set by setMode *)

PROCEDURE IsLowException (): BOOLEAN;
  (* Returns TRUE if the current coroutine is in the exceptional execution state
    because of the raising of an exception in a routine from this module; otherwise
    returns FALSE.
  *)

END LowReal.
```



```
PROCEDURE fractpart (x: SHORTREAL): SHORTREAL;
  (* Returns the fractional part of x *)

PROCEDURE scale (x: SHORTREAL; n: INTEGER): SHORTREAL;
  (* Returns the value of x * radix ** n *)

PROCEDURE trunc (x: SHORTREAL; n: INTEGER): SHORTREAL;
  (* Returns the value of the first n places of x *)

PROCEDURE round (x: SHORTREAL; n: INTEGER): SHORTREAL;
  (* Returns the value of x rounded to the first n places *)

PROCEDURE synthesize (expart: INTEGER; frapart: SHORTREAL): SHORTREAL;
  (* Returns a value of the type SHORTREAL constructed from the given expart and frapart *)

PROCEDURE setMode (m: Modes);
  (* Sets status flags appropriate to the underlying implementation of the type SHORTREAL *)

PROCEDURE currentMode (): Modes;
  (* Returns the current status flags in the form set by setMode *)

PROCEDURE IsLowException (): BOOLEAN;
  (* Returns TRUE if the current coroutine is in the exceptional execution state
     because of the raising of an exception in a routine from this module; otherwise
     returns FALSE.
  *)

END LowShort.
```

## 4.4.26 gm2-libs-iso/M2EXCEPTION

```
DEFINITION MODULE M2EXCEPTION;
```

```
(* Provides facilities for identifying language exceptions *)
```

```
TYPE
```

```
  M2Exceptions =
```

```
    (indexException,      rangeException,      caseSelectException,  invalidLocation
     functionException,   wholeValueException, wholeDivException,  realValueExcept
     realDivException,   complexValueException, complexDivException,  protException,
     sysException,       coException,           exException
    );
```

```
PROCEDURE M2Exception (): M2Exceptions;
```

```
(* If the current coroutine is in the exceptional execution state because of the raising
   of a language exception, returns the corresponding enumeration value, and otherwise
   raises an exception.
*)
```

```
PROCEDURE IsM2Exception (): BOOLEAN;
```

```
(* If the current coroutine is in the exceptional execution state because of the raising
   of a language exception, returns TRUE, and otherwise returns FALSE.
*)
```

```
END M2EXCEPTION.
```

#### 4.4.27 gm2-libs-iso/M2RTS

```

DEFINITION MODULE M2RTS ;

FROM SYSTEM IMPORT ADDRESS ;

TYPE
  ArgCEnvP = PROCEDURE (INTEGER, ADDRESS, ADDRESS) ;

PROCEDURE ConstructModules (applicationmodule, libname: ADDRESS;
                           overridesborder: ADDRESS;
                           argc: INTEGER; argv, envp: ADDRESS) ;

PROCEDURE DeconstructModules (applicationmodule, libname: ADDRESS;
                              argc: INTEGER; argv, envp: ADDRESS) ;

(*
  RegisterModule - adds module name to the list of outstanding
                  modules which need to have their dependencies
                  explored to determine initialization order.
*)

PROCEDURE RegisterModule (name, libname: ADDRESS;
                          init, fini: ArgCEnvP;
                          dependencies: PROC) ;

(*
  RequestDependant - used to specify that modulename is dependant upon
                    module dependantmodule.
*)

PROCEDURE RequestDependant (modulename, libname,
                           dependantmodule, dependantlibname: ADDRESS) ;

(*
  ExecuteTerminationProcedures - calls each installed termination
                                procedure in reverse order.
*)

PROCEDURE ExecuteTerminationProcedures ;

```

```
(*
  InstallTerminationProcedure - installs a procedure, p, which will
                              be called when the procedure
                              ExecuteTerminationProcedures
                              is invoked. It returns TRUE if the
                              procedure is installed.
*)

PROCEDURE InstallTerminationProcedure (p: PROC) : BOOLEAN ;

(*
  ExecuteInitialProcedures - executes the initial procedures installed
                              by InstallInitialProcedure.
*)

PROCEDURE ExecuteInitialProcedures ;

(*
  InstallInitialProcedure - installs a procedure to be executed just
                              before the BEGIN code section of the main
                              program module.
*)

PROCEDURE InstallInitialProcedure (p: PROC) : BOOLEAN ;

(*
  HALT - terminate the current program. The procedure
         ExecuteTerminationProcedures
         is called before the program is stopped. The parameter
         exitcode is optional. If the parameter is not supplied
         HALT will call libc 'abort', otherwise it will exit with
         the code supplied. Supplying a parameter to HALT has the
         same effect as calling ExitOnHalt with the same code and
         then calling HALT with no parameter.
*)

PROCEDURE HALT ([exitcode: INTEGER = -1]) <* noreturn *> ;

(*
  Halt - provides a more user friendly version of HALT, which takes
         four parameters to aid debugging. It writes an error message
         to stderr and calls exit (1).
*)
```

```

PROCEDURE Halt (description, filename, function: ARRAY OF CHAR;
               line: CARDINAL) <* noreturn *> ;

(*
  HaltC - provides a more user friendly version of HALT, which takes
          four parameters to aid debugging. It writes an error message
          to stderr and calls exit (1).
*)

PROCEDURE HaltC (description, filename, function: ADDRESS;
               line: CARDINAL) <* noreturn *> ;

(*
  ExitOnHalt - if HALT is executed then call exit with the exit code, e.
*)

PROCEDURE ExitOnHalt (e: INTEGER) ;

(*
  ErrorMessage - emits an error message to stderr and then calls exit (1).
*)

PROCEDURE ErrorMessage (message: ARRAY OF CHAR;
                      filename: ARRAY OF CHAR;
                      line: CARDINAL;
                      function: ARRAY OF CHAR) <* noreturn *> ;

(*
  IsTerminating - Returns true if any coroutine has started program termination
                  and false otherwise.
*)

PROCEDURE IsTerminating () : BOOLEAN ;

(*
  HasHalted - Returns true if a call to HALT has been made and false
              otherwise.
*)

PROCEDURE HasHalted () : BOOLEAN ;

```





```
    res indicates the reason, and cid identifies the invalid channel.  
*)
```

```
PROCEDURE OpenRead (VAR cid: ChanId; flags: FlagSet;  
    VAR res: OpenResults;  
    buffer: ADDRESS; length: CARDINAL;  
    deallocOnClose: BOOLEAN) ;
```

```
(*  
    Close - if the channel identified by cid is not open to  
            a memory stream, the exception wrongDevice is  
            raised; otherwise closes the channel, and assigns  
            the value identifying the invalid channel to cid.  
*)
```

```
PROCEDURE Close (VAR cid: ChanId) ;
```

```
(*  
    Rewrite - assigns the buffer index to zero. Subsequent  
              writes will overwrite the previous buffer contents.  
*)
```

```
PROCEDURE Rewrite (cid: ChanId) ;
```

```
(*  
    Reread - assigns the buffer index to zero. Subsequent  
             reads will read the previous buffer contents.  
*)
```

```
PROCEDURE Reread (cid: ChanId) ;
```

```
(*  
    IsMem - tests if the channel identified by cid is open as  
            a memory stream.  
*)
```

```
PROCEDURE IsMem (cid: ChanId) : BOOLEAN ;
```

```
END MemStream.
```

#### 4.4.29 gm2-libs-iso/Preemptive

```
DEFINITION MODULE Preemptive ;
```

```
(*  
  initPreemptive - if microsecs > 0 then turn on preemptive scheduling.  
                  if microsecs = 0 then preemptive scheduling is turned off.■  
*)
```

```
PROCEDURE initPreemptive (seconds, microsecs: CARDINAL) ;
```

```
END Preemptive.
```

#### 4.4.30 gm2-libs-iso/Processes

```
DEFINITION MODULE Processes;
```

```
  (* This module allows concurrent algorithms to be expressed using
     processes. A process is a unit of a program that has the
     potential to run in parallel with other processes.
  *)
```

```
IMPORT SYSTEM;
```

```
TYPE
```

```
  ProcessId;                (* Used to identify processes *)
  Parameter    = SYSTEM.ADDRESS; (* Used to pass data between processes *)
  Body         = PROC;        (* Used as the type of a process body *)
  Urgency      = INTEGER;     (* Used by the internal scheduler *)
  Sources      = CARDINAL;    (* Used to identify event sources *)
  ProcessesExceptions =      (* Exceptions raised by this module *)
    (passiveProgram, processError);
```

```
  (* The following procedures create processes and switch control between
     them. *)
```

```
PROCEDURE Create (procBody: Body; extraSpace: CARDINAL; procUrg: Urgency;
                 procParams: Parameter; VAR procId: ProcessId);
```

```
  (* Creates a new process with procBody as its body, and with urgency
     and parameters given by procUrg and procParams. At least as
     much workspace (in units of SYSTEM.LOC) as is specified by
     extraSpace is allocated to the process.
     An identity for the new process is returned in procId.
     The process is created in the passive state; it will not run
     until activated.
  *)
```

```
PROCEDURE Start (procBody: Body; extraSpace: CARDINAL; procUrg: Urgency;
                procParams: Parameter; VAR procId: ProcessId);
```

```
  (* Creates a new process, with parameters as for Create.
     The process is created in the ready state; it is eligible to
     run immediately.
  *)
```

```
PROCEDURE StopMe ();
```

```
  (* Terminates the calling process.
     The process must not be associated with a source of events.
  *)
```

```
PROCEDURE SuspendMe ();
```

```
(* Causes the calling process to enter the passive state. The
  procedure only returns when the calling process is again
  activated by another process.
*)

PROCEDURE Activate (procId: ProcessId);
  (* Causes the process identified by procId to enter the ready
    state, and thus to become eligible to run again.
  *)

PROCEDURE SuspendMeAndActivate (procId: ProcessId);
  (* Executes an atomic sequence of SuspendMe() and
    Activate(procId). *)

PROCEDURE Switch (procId: ProcessId; VAR info: Parameter);
  (* Causes the calling process to enter the passive state; the
    process identified by procId becomes the currently executing
    process. info is used to pass parameter information from the
    calling to the activated process. On return, info will
    contain information from the process that chooses to switch
    back to this one (or will be NIL if Activate or
    SuspendMeAndActivate are used instead of Switch).
  *)

PROCEDURE Wait ();
  (* Causes the calling process to enter the waiting state.
    The procedure will return when the calling process is
    activated by another process, or when one of its associated
    eventSources has generated an event.
  *)

(* The following procedures allow the association of processes
  with sources of external events.
*)

PROCEDURE Attach (eventSource: Sources);
  (* Associates the specified eventSource with the calling
    process. *)

PROCEDURE Detach (eventSource: Sources);
  (* Dissociates the specified eventSource from the program. *)

PROCEDURE IsAttached (eventSource: Sources): BOOLEAN;
  (* Returns TRUE if and only if the specified eventSource is
    currently associated with one of the processes of the
    program.
  *)
```

```
PROCEDURE Handler (eventSource: Sources): ProcessId;
    (* Returns the identity of the process, if any, that is
       associated with the specified eventSource.
    *)

(* The following procedures allow processes to obtain their
   identity, parameters, and urgency.
*)

PROCEDURE Me (): ProcessId;
    (* Returns the identity of the calling process (as assigned
       when the process was first created).
    *)

PROCEDURE MyParam (): Parameter;
    (* Returns the value specified as procParams when the calling
       process was created. *)

PROCEDURE UrgencyOf (procId: ProcessId): Urgency;
    (* Returns the urgency established when the process identified
       by procId was first created.
    *)

(* The following procedure provides facilities for exception
   handlers. *)

PROCEDURE ProcessesException (): ProcessesExceptions;
    (* If the current coroutine is in the exceptional execution state
       because of the raising of a language exception, returns the
       corresponding enumeration value, and otherwise raises an
       exception.
    *)

PROCEDURE IsProcessesException (): BOOLEAN;
    (* Returns TRUE if the current coroutine is in the exceptional
       execution state because of the raising of an exception in
       a routine from this module; otherwise returns FALSE.
    *)

(*
   Reschedule - rotates the ready queue and transfers to the process
                 with the highest run priority.
*)

PROCEDURE Reschedule ;
```

```
(*  
    displayProcesses -  
*)  
  
PROCEDURE displayProcesses (message: ARRAY OF CHAR) ;  
  
END Processes.
```

#### 4.4.31 gm2-libs-iso/ProgramArgs

```
DEFINITION MODULE ProgramArgs;

    (* Access to program arguments *)

IMPORT IOChan;

TYPE
    ChanId = IOChan.ChanId;

PROCEDURE ArgChan (): ChanId;
    (* Returns a value that identifies a channel for reading
       program arguments *)

PROCEDURE IsArgPresent (): BOOLEAN;
    (* Tests if there is a current argument to read from.  If not,
       read <= IOChan.CurrentFlags() will be FALSE, and attempting
       to read from the argument channel will raise the exception
       notAvailable.
    *)

PROCEDURE NextArg ();
    (* If there is another argument, causes subsequent input from the
       argument device to come from the start of the next argument.
       Otherwise there is no argument to read from, and a call of
       IsArgPresent will return FALSE.
    *)

END ProgramArgs.
```



```
p2: ADDRESS;  
p3: ADDRESS;  
p4: ADDRESS;  
p5: ADDRESS) : INTEGER ;
```

```
END RTco.
```

#### 4.4.33 gm2-libs-iso/RTdata

```

DEFINITION MODULE RTdata ;

  (*
    Description: provides a mechanism whereby devices can store
                data attached to a device.
  *)

  FROM SYSTEM IMPORT ADDRESS ;
  FROM IOLink IMPORT DeviceTablePtr ;

  TYPE
    ModuleId ;
    FreeProcedure = PROCEDURE (ADDRESS) ;

  (*
    MakeModuleId - creates a unique module Id.
  *)

  PROCEDURE MakeModuleId (VAR m: ModuleId) ;

  (*
    InitData - adds, datum, to the device, d. The datum
              is associated with ModuleID, m.
  *)

  PROCEDURE InitData (d: DeviceTablePtr; m: ModuleId;
                    datum: ADDRESS; f: FreeProcedure) ;

  (*
    GetData - returns the datum associated with ModuleId, m.
  *)

  PROCEDURE GetData (d: DeviceTablePtr; m: ModuleId) : ADDRESS ;

  (*
    KillData - destroys the datum associated with ModuleId, m,
              in device, d. It invokes the free procedure
              given during InitData.
  *)

  PROCEDURE KillData (d: DeviceTablePtr; m: ModuleId) ;

```

```
END RTdata.
```





```
        VAR actual: CARDINAL) : BOOLEAN ;

(*
   dowbytes - writes up to, nBytes.  It returns FALSE
              if an error occurred and it sets actual
              to the amount of data written.
*)

PROCEDURE dowbytes (g: GenDevIF;
                   d: DeviceTablePtr;
                   from: ADDRESS;
                   nBytes: CARDINAL;
                   VAR actual: CARDINAL) : BOOLEAN ;

(*
   dowriteln - attempt to write an end of line marker to the
               file and returns TRUE if successful.
*)

PROCEDURE dowriteln (g: GenDevIF; d: DeviceTablePtr) : BOOLEAN ;

(*
   iseof - returns TRUE if end of file has been seen.
*)

PROCEDURE iseof (g: GenDevIF; d: DeviceTablePtr) : BOOLEAN ;

(*
   iseoln - returns TRUE if end of line has been seen.
*)

PROCEDURE iseoln (g: GenDevIF; d: DeviceTablePtr) : BOOLEAN ;

(*
   iserror - returns TRUE if an error was seen on the device.
             Note that reaching EOF is not classified as an
             error.
*)

PROCEDURE iserror (g: GenDevIF; d: DeviceTablePtr) : BOOLEAN ;

END RTfio.
```





\*)

```
PROCEDURE checkErrno (g: ChanDev; d: DeviceTablePtr) ;
```

```
END RTgen.
```





















```
        execution state because of the raising of an exception in a  
        routine from this module; otherwise returns FALSE.  
*)
```

```
END RealConv.
```



```
*)  
  
PROCEDURE WriteReal (cid: IOChan.ChanId;  
                    real: REAL; width: CARDINAL);  
  (* Writes the value of real to cid, as WriteFixed if the sign  
    and magnitude can be shown in the given width, or otherwise  
    as WriteFloat. The number of places or significant digits  
    depends on the given width.  
  *)  
  
END RealIO.
```























































```
                                flags: FlagSet; VAR res: OpenResults);
(*
  Attempts to obtain and open a channel connected to a stored
  rewindable file of the given name. The write and old flags
  are implied; without the raw flag, text is implied. If
  successful, assigns to cid the identity of the opened channel,
  assigns the value opened to res, and selects output mode,
  with the write position corresponding to the length of the
  file. If a channel cannot be opened as required, the value
  of res indicates the reason, and cid identifies the invalid
  channel.
*)

PROCEDURE OpenRead (VAR cid: ChanId; name: ARRAY OF CHAR;
                    flags: FlagSet; VAR res: OpenResults);
(* Attempts to obtain and open a channel connected to a stored
  rewindable file of the given name.
  The read and old flags are implied; without the raw flag,
  text is implied. If successful, assigns to cid the
  identity of the opened channel, assigns the value opened to
  res, and selects input mode, with the read position
  corresponding to the start of the file.
  If a channel cannot be opened as required, the value of
  res indicates the reason, and cid identifies the invalid
  channel.
*)

PROCEDURE IsSeqFile (cid: ChanId): BOOLEAN;
(* Tests if the channel identified by cid is open to a
  rewindable sequential file. *)

PROCEDURE Reread (cid: ChanId);
(* If the channel identified by cid is not open to a rewindable
  sequential file, the exception wrongDevice is raised;
  otherwise attempts to set the read position to the
  start of the file, and to select input mode.
  If the operation cannot be performed (perhaps because of
  insufficient permissions) neither input mode nor output
  mode is selected.
*)

PROCEDURE Rewrite (cid: ChanId);
(* If the channel identified by cid is not open to a
  rewindable sequential file, the exception wrongDevice is
  raised; otherwise, attempts to truncate the file to zero
  length, and to select output mode. If the operation
  cannot be performed (perhaps because of insufficient
```

```
        permissions) neither input mode nor output mode is selected.
    *)

PROCEDURE Close (VAR cid: ChanId);
    (* If the channel identified by cid is not open to a rewindable
       sequential file, the exception wrongDevice is raised;
       otherwise closes the channel, and assigns the value
       identifying the invalid channel to cid.
    *)

END SeqFile.
```

#### 4.4.58 gm2-libs-iso/ShortComplexMath

```

DEFINITION MODULE ShortComplexMath;

  (* Mathematical functions for the type SHORTCOMPLEX *)

CONST
  i =      CMPLX (0.0, 1.0);
  one =    CMPLX (1.0, 0.0);
  zero =   CMPLX (0.0, 0.0);

PROCEDURE abs (z: SHORTCOMPLEX): SHORTREAL;
  (* Returns the length of z *)

PROCEDURE arg (z: SHORTCOMPLEX): SHORTREAL;
  (* Returns the angle that z subtends to the positive real axis *)

PROCEDURE conj (z: SHORTCOMPLEX): SHORTCOMPLEX;
  (* Returns the complex conjugate of z *)

PROCEDURE power (base: SHORTCOMPLEX; exponent: SHORTREAL): SHORTCOMPLEX;
  (* Returns the value of the number base raised to the power exponent *)

PROCEDURE sqrt (z: SHORTCOMPLEX): SHORTCOMPLEX;
  (* Returns the principal square root of z *)

PROCEDURE exp (z: SHORTCOMPLEX): SHORTCOMPLEX;
  (* Returns the complex exponential of z *)

PROCEDURE ln (z: SHORTCOMPLEX): SHORTCOMPLEX;
  (* Returns the principal value of the natural logarithm of z *)

PROCEDURE sin (z: SHORTCOMPLEX): SHORTCOMPLEX;
  (* Returns the sine of z *)

PROCEDURE cos (z: SHORTCOMPLEX): SHORTCOMPLEX;
  (* Returns the cosine of z *)

PROCEDURE tan (z: SHORTCOMPLEX): SHORTCOMPLEX;
  (* Returns the tangent of z *)

PROCEDURE arcsin (z: SHORTCOMPLEX): SHORTCOMPLEX;
  (* Returns the arcsine of z *)

PROCEDURE arccos (z: SHORTCOMPLEX): SHORTCOMPLEX;
  (* Returns the arccosine of z *)

```

```
PROCEDURE arctan (z: SHORTCOMPLEX): SHORTCOMPLEX;
    (* Returns the arctangent of z *)

PROCEDURE polarToComplex (abs, arg: SHORTREAL): SHORTCOMPLEX;
    (* Returns the complex number with the specified polar coordinates *)

PROCEDURE scalarMult (scalar: SHORTREAL; z: SHORTCOMPLEX): SHORTCOMPLEX;
    (* Returns the scalar product of scalar with z *)

PROCEDURE IsCMathException (): BOOLEAN;
    (* Returns TRUE if the current coroutine is in the exceptional execution state
       because of the raising of an exception in a routine from this module; otherwise
       returns FALSE.
    *)

END ShortComplexMath.
```

## 4.4.59 gm2-libs-iso/ShortConv

```

DEFINITION MODULE ShortConv;

IMPORT
    ConvTypes;

TYPE
    ConvResults = ConvTypes.ConvResults; (* strAllRight, strOutOfRange,
                                           strWrongFormat, strEmpty *)

PROCEDURE ScanReal (inputCh: CHAR; VAR chClass: ConvTypes.ScanClass;
                   VAR nextState: ConvTypes.ScanState);
    (* Represents the start state of a finite state scanner for real
       numbers - assigns class of inputCh to chClass and a procedure
       representing the next state to nextState.
    *)

PROCEDURE FormatReal (str: ARRAY OF CHAR): ConvResults;
    (* Returns the format of the string value for conversion to LONGREAL. *)

PROCEDURE ValueReal (str: ARRAY OF CHAR): SHORTREAL;
    (* Returns the value corresponding to the real number string value
       str if str is well-formed; otherwise raises the ShortConv exception.
    *)

PROCEDURE LengthFloatReal (real: SHORTREAL; sigFigs: CARDINAL): CARDINAL;
    (* Returns the number of characters in the floating-point string
       representation of real with sigFigs significant figures.
    *)

PROCEDURE LengthEngReal (real: SHORTREAL; sigFigs: CARDINAL): CARDINAL;
    (* Returns the number of characters in the floating-point engineering
       string representation of real with sigFigs significant figures.
    *)

PROCEDURE LengthFixedReal (real: SHORTREAL; place: INTEGER): CARDINAL;
    (* Returns the number of characters in the fixed-point string
       representation of real rounded to the given place relative to the
       decimal point.
    *)

PROCEDURE IsRConvException (): BOOLEAN;
    (* Returns TRUE if the current coroutine is in the exceptional
       execution state because of the raising of an exception in a
       routine from this module; otherwise returns FALSE.
    *)

```

END ShortConv.



```
*)  
  
PROCEDURE WriteReal (cid: IOChan.ChanId; real: SHORTREAL;  
                    width: CARDINAL);  
  (* Writes the value of real to cid, as WriteFixed if the  
    sign and magnitude can be shown in the given width, or  
    otherwise as WriteFloat. The number of places or  
    significant digits depends on the given width.  
  *)  
  
END ShortIO.
```

#### 4.4.61 gm2-libs-iso/ShortMath

```

DEFINITION MODULE ShortMath;

  (* Mathematical functions for the type LONGREAL *)

CONST
  pi    = 3.1415926535897932384626433832795028841972;
  exp1  = 2.7182818284590452353602874713526624977572;

PROCEDURE __BUILTIN__ sqrt (x: SHORTREAL): SHORTREAL;
  (* Returns the positive square root of x *)

PROCEDURE __BUILTIN__ exp (x: SHORTREAL): SHORTREAL;
  (* Returns the exponential of x *)

PROCEDURE __BUILTIN__ ln (x: SHORTREAL): SHORTREAL;
  (* Returns the natural logarithm of x *)

  (* The angle in all trigonometric functions is measured in radians *)

PROCEDURE __BUILTIN__ sin (x: SHORTREAL): SHORTREAL;
  (* Returns the sine of x *)

PROCEDURE __BUILTIN__ cos (x: SHORTREAL): SHORTREAL;
  (* Returns the cosine of x *)

PROCEDURE tan (x: SHORTREAL): SHORTREAL;
  (* Returns the tangent of x *)

PROCEDURE arcsin (x: SHORTREAL): SHORTREAL;
  (* Returns the arcsine of x *)

PROCEDURE arccos (x: SHORTREAL): SHORTREAL;
  (* Returns the arccosine of x *)

PROCEDURE arctan (x: SHORTREAL): SHORTREAL;
  (* Returns the arctangent of x *)

PROCEDURE power (base, exponent: SHORTREAL): SHORTREAL;
  (* Returns the value of the number base raised to the power exponent *)■

PROCEDURE round (x: SHORTREAL): INTEGER;
  (* Returns the value of x rounded to the nearest integer *)

PROCEDURE IsRMathException (): BOOLEAN;
  (* Returns TRUE if the current coroutine is in the exceptional

```

```
        execution state because of the raising of an exception in a  
        routine from this module; otherwise returns FALSE.  
*)
```

```
END ShortMath.
```

#### 4.4.62 gm2-libs-iso/ShortStr

```

DEFINITION MODULE ShortStr;

  (* SHORTREAL/string conversions *)

IMPORT
  ConvTypes;

TYPE
  (* strAllRight, strOutOfRange, strWrongFormat, strEmpty *)
  ConvResults = ConvTypes.ConvResults;

  (* the string form of a signed fixed-point real number is
     ["+" | "-"], decimal digit, {decimal digit}, [".",
     {decimal digit}]
  *)

  (* the string form of a signed floating-point real number is
     signed fixed-point real number, "E", ["+" | "-"],
     decimal digit, {decimal digit}
  *)

PROCEDURE StrToReal (str: ARRAY OF CHAR; VAR real: SHORTREAL;
  VAR res: ConvResults);
  (* Ignores any leading spaces in str. If the subsequent characters
     in str are in the format of a signed real number, assigns a
     corresponding value to real. Assigns a value indicating the
     format of str to res.
  *)

PROCEDURE RealToFloat (real: SHORTREAL; sigFigs: CARDINAL;
  VAR str: ARRAY OF CHAR);
  (* Converts the value of real to floating-point string form, with
     sigFigs significant figures, and copies the possibly truncated
     result to str.
  *)

PROCEDURE RealToEng (real: SHORTREAL; sigFigs: CARDINAL;
  VAR str: ARRAY OF CHAR);
  (* Converts the value of real to floating-point string form, with
     sigFigs significant figures, and copies the possibly truncated
     result to str. The number is scaled with one to three digits
     in the whole number part and with an exponent that is a
     multiple of three.
  *)

```

```
PROCEDURE RealToFixed (real: SHORTREAL; place: INTEGER;
                      VAR str: ARRAY OF CHAR);
  (* Converts the value of real to fixed-point string form, rounded
     to the given place relative to the decimal point, and copies
     the possibly truncated result to str.
  *)

PROCEDURE RealToStr (real: SHORTREAL; VAR str: ARRAY OF CHAR);
  (* Converts the value of real as RealToFixed if the sign and
     magnitude can be shown within the capacity of str, or
     otherwise as RealToFloat, and copies the possibly truncated
     result to str. The number of places or significant digits
     depend on the capacity of str.
  *)

END ShortStr.
```











































```
(* Returns the value corresponding to the unsigned whole number string
   value str if str is well-formed; otherwise raises the WholeConv
   exception.
*)

PROCEDURE LengthCard (card: CARDINAL): CARDINAL;
  (* Returns the number of characters in the string representation of
     card.
  *)

PROCEDURE IsWholeConvException (): BOOLEAN;
  (* Returns TRUE if the current coroutine is in the exceptional execution
     state because of the raising of an exception in a routine from this
     module; otherwise returns FALSE.
  *)

END WholeConv.
```



## 4.4.77 gm2-libs-iso/WholeStr

```

DEFINITION MODULE WholeStr;

    (* Whole-number/string conversions *)

IMPORT
    ConvTypes;

TYPE
    ConvResults = ConvTypes.ConvResults;
    (* strAllRight, strOutOfRange, strWrongFormat, strEmpty *)

    (* the string form of a signed whole number is
       ["+" | "-"], decimal digit, {decimal digit}
    *)

PROCEDURE StrToInt (str: ARRAY OF CHAR; VAR int: INTEGER;
                   VAR res: ConvResults);
    (* Ignores any leading spaces in str. If the subsequent
       characters in str are in the format of a signed whole
       number, assigns a corresponding value to int. Assigns
       a value indicating the format of str to res.
    *)

PROCEDURE IntToStr (int: INTEGER; VAR str: ARRAY OF CHAR);
    (* Converts the value of int to string form and copies the
       possibly truncated result to str. *)

    (* the string form of an unsigned whole number is
       decimal digit, {decimal digit}
    *)

PROCEDURE StrToCard (str: ARRAY OF CHAR;
                   VAR card: CARDINAL;
                   VAR res: ConvResults);
    (* Ignores any leading spaces in str. If the subsequent
       characters in str are in the format of an unsigned
       whole number, assigns a corresponding value to card.
       Assigns a value indicating the format of str to res.
    *)

PROCEDURE CardToStr (card: CARDINAL; VAR str: ARRAY OF CHAR);
    (* Converts the value of card to string form and copies the
       possibly truncated result to str. *)

END WholeStr.

```

#### 4.4.78 gm2-libs-iso/wrapclock

```

DEFINITION MODULE wrapclock ;

FROM SYSTEM IMPORT ADDRESS ;

TYPE
    timespec = ADDRESS ;

(*
    timezone - return the glibc timezone value.
               This contains the difference between UTC and the latest
               local standard time, in seconds west of UTC.
               If the underlying timezone is unavailable and
               clock_gettime, localtime_r, tm_gmtoff
               is unavailable then 0 is returned.
*)

PROCEDURE timezone () : LONGINT ;

(*
    istimezone returns 1 if timezone in wrapclock.cc can resolve the
               timezone value using the timezone C library call or by using
               clock_gettime, localtime_r and tm_gmtoff.
*)

PROCEDURE istimezone () : INTEGER ;

(*
    daylight - return the glibc daylight value.
               This variable has a nonzero value if Daylight Saving
               Time rules apply.
               A nonzero value does not necessarily mean that Daylight
               Saving Time is now in effect; it means only that Daylight
               Saving Time is sometimes in effect.
*)

PROCEDURE daylight () : INTEGER ;

(*
    isdst - returns 1 if daylight saving time is currently in effect and
            returns 0 if it is not.
*)

```



```
(*
  GetTimeRealtime - performs return gettimeofday (CLOCK_REALTIME, ts).
                    gettimeofday returns 0 on success and -1 on failure.
                    If the underlying system does not have gettimeofday
                    then GetTimeRealtime returns 1.
*)
```

```
PROCEDURE GetTimeRealtime (ts: timespec) : INTEGER ;
```

```
(*
  SetTimeRealtime - performs return settimeofday (CLOCK_REALTIME, ts).
                    gettimeofday returns 0 on success and -1 on failure.
                    If the underlying system does not have gettimeofday
                    then SetTimeRealtime returns 1.
*)
```

```
PROCEDURE SetTimeRealtime (ts: timespec) : INTEGER ;
```

```
END wrapclock.
```

**4.4.79 gm2-libs-iso/wrapsock**

```

DEFINITION MODULE wrapsock ;

(*
   Description: provides a set of wrappers to some client side
                tcp socket primitives.
*)

FROM SYSTEM IMPORT ADDRESS ;
FROM ChanConsts IMPORT OpenResults ;

TYPE
  clientInfo = ADDRESS ;

(*
   clientOpen - returns an ISO Modula-2 OpenResult.
                It attempts to connect to:  hostname:portNo.
                If successful then the data structure, c,
                will have its fields initialized.
*)

PROCEDURE clientOpen (c: clientInfo;
                     hostname: ADDRESS;
                     length: CARDINAL;
                     portNo: CARDINAL) : OpenResults ;

(*
   clientOpenIP - returns an ISO Modula-2 OpenResult.
                  It attempts to connect to:  ipaddress:portNo.
                  If successful then the data structure, c,
                  will have its fields initialized.
*)

PROCEDURE clientOpenIP (c: clientInfo;
                       ip: CARDINAL;
                       portNo: CARDINAL) : OpenResults ;

(*
   getClientPortNo - returns the portNo from structure, c.
*)

PROCEDURE getClientPortNo (c: clientInfo) : CARDINAL ;

```

```
(*
  getClientHostname - fills in the hostname of the server
                    the to which the client is connecting.
*)

PROCEDURE getClientHostname (c: clientInfo;
                           hostname: ADDRESS; high: CARDINAL) ;

(*
  getClientSocketFd - returns the sockFd from structure, c.
*)

PROCEDURE getClientSocketFd (c: clientInfo) : INTEGER ;

(*
  getClientIP - returns the sockFd from structure, s.
*)

PROCEDURE getClientIP (c: clientInfo) : CARDINAL ;

(*
  getPushBackChar - returns TRUE if a pushed back character
                  is available.
*)

PROCEDURE getPushBackChar (c: clientInfo; VAR ch: CHAR) : BOOLEAN ;

(*
  setPushBackChar - returns TRUE if it is able to push back a
                  character.
*)

PROCEDURE setPushBackChar (c: clientInfo; ch: CHAR) : BOOLEAN ;

(*
  getSizeOfClientInfo - returns the sizeof (opaque data type).
*)

PROCEDURE getSizeOfClientInfo () : CARDINAL ;
```

```
END wrapsock.
```

**4.4.80 gm2-libs-iso/wraptime**

```

DEFINITION MODULE wraptime ;

(*
   Description: provides an interface to various time related
                entities on the underlying host operating system.
                It provides access to the glibc/libc functions:
                gettimeofday, settimeofday and localtime_r.
*)

FROM SYSTEM IMPORT ADDRESS ;

TYPE
    timeval  = ADDRESS ;
    timezone = ADDRESS ;
    tm       = ADDRESS ;

(*
   InitTimeval - returns a newly created opaque type.
*)

PROCEDURE InitTimeval () : timeval ;

(*
   KillTimeval - deallocates the memory associated with an
                opaque type.
*)

PROCEDURE KillTimeval (tv: timeval) : timeval ;

(*
   InitTimezone - returns a newly created opaque type.
*)

PROCEDURE InitTimezone () : timezone ;

(*
   KillTimezone - deallocates the memory associated with an
                opaque type.
*)

PROCEDURE KillTimezone (tv: timezone) : timezone ;

```

```
(*  
    InitTM - returns a newly created opaque type.  
*)
```

```
PROCEDURE InitTM () : tm ;
```

```
(*  
    KillTM - deallocates the memory associated with an  
             opaque type.  
*)
```

```
PROCEDURE KillTM (tv: tm) : tm ;
```

```
(*  
    gettimeofday - calls gettimeofday(2) with the same parameters, tv,  
                  and, tz. It returns 0 on success.  
*)
```

```
PROCEDURE gettimeofday (tv: timeval; tz: timezone) : INTEGER ;
```

```
(*  
    settimeofday - calls settimeofday(2) with the same parameters, tv,  
                  and, tz. It returns 0 on success.  
*)
```

```
PROCEDURE settimeofday (tv: timeval; tz: timezone) : INTEGER ;
```

```
(*  
    GetFractions - returns the tv_usec field inside the timeval structure  
                  as a CARDINAL.  
*)
```

```
PROCEDURE GetFractions (tv: timeval) : CARDINAL ;
```

```
(*  
    localtime_r - returns the tm parameter, m, after it has been assigned with  
                  appropriate contents determined by, tv. Notice that  
                  this procedure function expects, timeval, as its first  
                  parameter and not a time_t (as expected by the posix  
                  equivalent). This avoids having to expose a time_t
```

```
                                system dependant definition.
*)

PROCEDURE localtime_r (tv: timeval; m: tm) : tm ;

(*
  GetYear - returns the year from the structure, m.
*)

PROCEDURE GetYear (m: tm) : CARDINAL ;

(*
  GetMonth - returns the month from the structure, m.
*)

PROCEDURE GetMonth (m: tm) : CARDINAL ;

(*
  GetDay - returns the day of the month from the structure, m.
*)

PROCEDURE GetDay (m: tm) : CARDINAL ;

(*
  GetHour - returns the hour of the day from the structure, m.
*)

PROCEDURE GetHour (m: tm) : CARDINAL ;

(*
  GetMinute - returns the minute within the hour from the structure, m.
*)

PROCEDURE GetMinute (m: tm) : CARDINAL ;

(*
  GetSecond - returns the seconds in the minute from the structure, m.
                The return value will always be in the range 0..59.
                A leap minute of value 60 will be truncated to 59.
*)
```

```
PROCEDURE GetSecond (m: tm) : CARDINAL ;

(*
  GetSummerTime - returns a boolean indicating whether summer time is
                  set.
*)

PROCEDURE GetSummerTime (tz: timezone) : BOOLEAN ;

(*
  GetDST - returns the number of minutes west of GMT.
*)

PROCEDURE GetDST (tz: timezone) : INTEGER ;

(*
  SetTimeval - sets the fields in timeval, tv, with:
               second, minute, hour, day, month, year, fractions.
*)

PROCEDURE SetTimeval (tv: timeval;
                    second, minute, hour, day,
                    month, year, yday, wday, isdst: CARDINAL) ;

(*
  SetTimezone - set the timezone field inside timeval, tv.
*)

PROCEDURE SetTimezone (tv: timeval;
                     zone: CARDINAL; minuteswest: INTEGER) ;

END wraptime.
```





























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