The GNU Modula-2 Compiler

For GCC version 16.0.1 (pre-release)

(GCC)

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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`'.

---

[1] 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`'. [1]

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.

---

[1] 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 on 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 prepossessed 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 the 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 'M2WIDESET'. By default this option is on. Wideset provision can be disabled by '-fno-wideset' and no reference will be made to the run time 'M2WIDESET' 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
=================
all     | turn on all flags below
module  | trace modules as they register themselves
hex     | display the hex address of the init/fini functions
warning | show any warnings
pre     | generate module list prior to dependency resolution
dep     | trace module dependency resolution
post    | generate module list after dependency resolution
force   | 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
======================================
INTEGER                  int
LONGINT                  long long int
```

```
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 53. See Section 2.23 [The ISO system module], page 57.

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
```

[2] '`-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    __LINE__                Constant Literal compatible
                                    with CARDINAL, INTEGER and WORD.
                                    Example 1234

anywhere    __FILE__                Constant string compatible
                                    with parameter ARRAY OF CHAR or
                                    an ARRAY whose SIZE is >= string
                                    length.  Example
                                    "hello.mod"

procedure   __FUNCTION__            Constant string compatible
```

```
                                        with parameter ARRAY OF CHAR or
                                        an ARRAY whose SIZE is >= 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 >= 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 53. See Section 2.23 [The ISO system module], page 57.

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 `CARDINAL`s 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 sentinal
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 `struct`ure 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 three definition modules and three implementation modules `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 link these objects into a shared library.

```
export LIBDIR=$(gm2 -print-file-name=)../../../../lib64

libtool --tag=CC --mode=link gcc -g a.lo b.lo c.lo \
  -L${LIBDIR} -rpath `pwd` -lm2pim -lm2iso -lstdc++ \
  -lm -o libabc.la
```

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

This library can be called from C++ using the following technique. The define `USER_LIB` is the name of the library dialect and maybe changed if required. The `DEFAULT_RUNTIME_MODULE_OVERRIDE` is a predefined string containing the default base core module initialization order.

```
#include <stdio.h>
#include <m2rts.h>

#define USER_LIB NULL

/* Add the runtime dependency for this file on modules a, b and c.  */

void
dep (void)
{
  m2iso_M2RTS_RequestDependant (__FILE__, USER_LIB, "c", USER_LIB);
  m2iso_M2RTS_RequestDependant (__FILE__, USER_LIB, "b", USER_LIB);
  m2iso_M2RTS_RequestDependant (__FILE__, USER_LIB, "a", USER_LIB);
}

void
```

```
init (int, char *[], char *[])
{
  printf ("test.c:init\n");
}

void
fini (int, char *[], char *[])
{
  printf ("test.c:fini\n");
}

void
construct_scaffold (int argc, char *argv[], char *envp[])
{
  m2iso_M2RTS_RegisterModule (__FILE__, USER_LIB,
                              init, fini, dep);
  m2iso_M2RTS_ConstructModules (__FILE__, USER_LIB,
                                DEFAULT_RUNTIME_MODULE_OVERRIDE,
                                argc, argv, envp);
}

void
deconstruct_scaffold (int argc, char *argv[], char *envp[])
{
  m2iso_M2RTS_DeconstructModules (__FILE__, USER_LIB,
                                  argc, argv, envp);
}

int
main (int argc, char *argv[], char *envp[])
{
  printf ("main starts\n");
  construct_scaffold (argc, argv, envp);
  printf ("main application goes here\n");
  deconstruct_scaffold (argc, argv, envp);
  printf ("main tidying up\n");
  return 0;
}
```

This source file can be compiled and linked using the following command:

```
export INCLUDE=$(gm2 -print-file-name=)/m2/m2iso
g++ -I${INCLUDE} -g test.c -L. -l:.libs/libabc.so -L${LIBDIR} -lm2iso
```

and finally run using:

```
LD_LIBRARY_PATH=.libs:${LIBDIR} ./a.out

main starts
init: module a
```

```
init: module b
init: module c
test.c:init
main application goes here
test.c:fini
finish: module c
finish: module b
finish: module a
main tidying up
```

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 to 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 to 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` commnads 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 38, for another example which uses the `UNQUALIFIED` keyword to reduce the module name clutter from the viewport 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 -lstdc++ -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 CARDINALs 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 `INTEGER`s. 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 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
   BITSPERLOC    = __ATTRIBUTE__ __BUILTIN__ ((BITS_PER_UNIT)) ;
   LOCSPERWORD   = __ATTRIBUTE__ __BUILTIN__ ((UNITS_PER_WORD)) ;
```

Built-in functions are transparent to the end user. All built-in functions are declared in `DEFINITION MODULE`s 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 intrincic 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 intrincic 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 BITSPERBYTE, BYTESPERWORD,
                 ADDRESS, WORD, BYTE, CSIZE_T, CSSIZE_T, COFF_T, CARDINAL64, (*
                 Target specific data types.  *)
                 ADR, TSIZE, ROTATE, SHIFT, THROW, TBITSIZE ;
                 (* SIZE is also exported if -fpim2 is used.  *)

CONST
  BITSPERBYTE   = __ATTRIBUTE__ __BUILTIN__ ((BITS_PER_UNIT)) ;
  BYTESPERWORD  = __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, 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:
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 BITSPERLOC, LOCSPERWORD,
                 LOC, BYTE, WORD, ADDRESS, CSIZE_T, CSSIZE_T, COFF_T, (*
                 Target specific data types.  *)
                 ADDADR, SUBADR, DIFADR, MAKEADR, ADR, ROTATE,
                 SHIFT, CAST, TSIZE,

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

```
                 THROW, TBITSIZE ;

CONST
                  (* <implementation-defined constant> ; *)
  BITSPERLOC    = __ATTRIBUTE__ __BUILTIN__ ((BITS_PER_UNIT)) ;
                  (* <implementation-defined constant> ; *)
  LOCSPERWORD   = __ATTRIBUTE__ __BUILTIN__ ((UNITS_PER_WORD)) ;
                  (* <implementation-defined constant> ; *)
  LOCSPERBYTE = 8 DIV BITSPERLOC ;

(* 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.  *)

(*
   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` 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` 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/>.

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Version 3, 29 June 2007

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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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   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.

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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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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' Varient { '|' Varient  }
             [ 'ELSE' FieldListSequence  ] 'END'
           =:

TagIdent := [ Ident  ]
          =:

CaseTag := TagIdent [ ':' Qualident  ]
```

```
         =:
Varient := [ VarientCaseLabelList ':' FieldListSequence  ]
         =:
VarientCaseLabelList := VarientCaseLabels { ',' VarientCaseLabels  }
                      =:
VarientCaseLabels := 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__ 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 intrincic 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 intrincic 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.
```

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 existance 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
                 occurances 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 occurance 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 occurance 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 occurance 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 occured 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 primatives)
*)

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.
```

4.1.23 gm2-libs/M2Dependent

```
DEFINITION MODULE M2Dependent ;

FROM SYSTEM IMPORT ADDRESS ;


TYPE
   ArgCVEnvP = PROCEDURE (INTEGER, ADDRESS, ADDRESS) ;


PROCEDURE ConstructModules (applicationmodule, libname,
                            overrideliborder: 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 (modulename, libname: ADDRESS;
                          init, fini:  ArgCVEnvP;
                          dependencies: PROC) ;


(*
   RequestDependant - used to specify that modulename:libname
                      is dependant upon
                      module dependantmodule:dependantlibname
*)

PROCEDURE RequestDependant (modulename, libname,
                            dependantmodule, dependantlibname: ADDRESS) ;


(*
   InstallTerminationProcedure - installs a procedure, p, which will
                                 be called when the procedure
                                 ExecuteTerminationProcedures
                                 is invoked.  It returns TRUE is 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 ;


(*
   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,    realValueException,
     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.
```

4.1.25 gm2-libs/M2RTS

```
DEFINITION MODULE M2RTS ;

FROM SYSTEM IMPORT ADDRESS ;


TYPE
   ArgCVEnvP = PROCEDURE (INTEGER, ADDRESS, ADDRESS) ;


PROCEDURE ConstructModules (applicationmodule, libname,
                            overrideliborder: 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:  ArgCVEnvP;
                          dependencies: PROC) ;


(*
   RequestDependant - used to specify that modulename is dependant upon
                      module dependantmodule.
*)

PROCEDURE RequestDependant (modulename, libname,
                            dependantmodule, dependantlibname: ADDRESS) ;


(*
   InstallTerminationProcedure - installs a procedure, p, which will
                                 be called when the procedure
                                 ExecuteTerminationProcedures
                                 is invoked.  It returns TRUE is 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 ;


(*
   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) <* noreturn *> ;
PROCEDURE ReturnException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE IncException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE DecException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE InclException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE ExclException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE ShiftException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE RotateException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE StaticArraySubscriptException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE DynamicArraySubscriptException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE ForLoopBeginException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE ForLoopToException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE ForLoopEndException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE PointerNilException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE NoReturnException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE CaseException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE WholeNonPosDivException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE WholeNonPosModException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE WholeZeroDivException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE WholeZeroRemException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE WholeValueException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE RealValueException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE ParameterException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE NoException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;


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 RTExceptions.
```

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 alteratively 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.
```

4.1.38 gm2-libs/SYSTEM

```
DEFINITION MODULE SYSTEM ;

EXPORT QUALIFIED BITSPERBYTE, BYTESPERWORD,
                 ADDRESS, WORD, BYTE, CSIZE_T, CSSIZE_T, COFF_T, CARDINAL64, (*
                 Target specific data types.  *)
                 ADR, TSIZE, ROTATE, SHIFT, THROW, TBITSIZE ;
                 (* SIZE is also exported if -fpim2 is used.  *)

CONST
  BITSPERBYTE   = __ATTRIBUTE__ __BUILTIN__ ((BITS_PER_UNIT)) ;
  BYTESPERWORD  = __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, 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:
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.
```

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 infront 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, hexidecimal numbers.
                     The value of lower is only used when hexidecimal
                     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, hexidecimal numbers.
                      The value of lower is only used when hexidecimal
                      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 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, hexidecimal numbers.
                         The value of lower is only used when hexidecimal
                         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) : LONGINT ;


(*
   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, hexidecimal numbers.
                          The value of lower is only used when hexidecimal
                          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) : LONGCARD ;


(*
   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, hexidecimal numbers.
                           The value of lower is only used when hexidecimal
                           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 - hexidecimal 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 - hexidecimal 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 InitExceptionHandlers (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.
```

4.1.54 gm2-libs/cgetopt

```
DEFINITION MODULE cgetopt ;

FROM SYSTEM IMPORT ADDRESS ;

TYPE
   Options = ADDRESS ;

VAR
   optarg                : ADDRESS ;
   optind, opterr, optopt: INTEGER ;


(*
   getopt - the getopt() function parses the command-line arguments.
            Its arguments argc and argv are the argument count and array as
            passed to the main() function on program invocation.  An element of
            argv that starts with '-' (and is not exactly "-" or "--") is an
            option element.  The characters of this element (aside from the
            initial '-') are option characters.  If getopt() is called
            repeatedly, it returns successively each of the option characters
            from each of the option elements.
*)

PROCEDURE getopt (argc: INTEGER; argv: ADDRESS; optstring: ADDRESS) : CHAR ;


(*
   getopt_long - works like getopt() except that it also accepts long options,
                 started with two dashes.  (If the program accepts only long
                 options, then optstring should be specified as an empty string (""),
                 not NULL.)  Long option names may be abbreviated if the abbreviation
                 is unique or is an exact match for some defined option.  A
                 long option may take a parameter, of the form --arg=param or
                 --arg param.
*)

PROCEDURE getopt_long (argc: INTEGER; argv: ADDRESS; optstring: ADDRESS;
                       longopts: ADDRESS; VAR longindex: INTEGER) : INTEGER ;


(*
   getopt_long_only - a wrapper for the C getopt_long_only.
*)

PROCEDURE getopt_long_only (argc: INTEGER; argv: ADDRESS; optstring: ADDRESS;
```

```
                            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.
```

4.1.60 gm2-libs/libc

```
DEFINITION MODULE FOR "C" libc ;

FROM SYSTEM IMPORT ADDRESS, CSIZE_T, CSSIZE_T, COFF_T ;

EXPORT UNQUALIFIED time_t, timeb, tm, ptrToTM,
                   atof, atoi, atol, atoll,
                   strtod, strtof, strtold, strtol, strtoll, strtoul, strtoull,
                   write, read,
                   system, abort,
                   malloc, free,
                   exit, isatty,
                   getenv, putenv, getpid,
                   dup, close, open, lseek,
                   readv, writev,
                   perror, creat,
                   getcwd, chown, strlen, strcpy, strncpy,
                   unlink, setenv,
                   memcpy, memset, memmove, printf, realloc,
                   rand, srand,
                   time, localtime, ftime,
                   shutdown, snprintf,
                   rename, setjmp, longjmp, atexit,
                   ttyname, sleep, execv ;


TYPE
   time_t = LONGINT ;

   ptrToTM = POINTER TO tm ;
   tm = RECORD
           tm_sec: INTEGER ;     (* Seconds.     [0-60] (1 leap second) *)
           tm_min: INTEGER ;     (* Minutes.     [0-59]   *)
           tm_hour: INTEGER ;    (* Hours.       [0-23]   *)
           tm_mday: INTEGER ;    (* Day.         [1-31]   *)
           tm_mon: INTEGER ;     (* Month.       [0-11]   *)
           tm_year: INTEGER ;    (* Year - 1900.          *)
           tm_wday: INTEGER ;    (* Day of week. [0-6]    *)
           tm_yday: INTEGER ;    (* Days in year.[0-365]  *)
           tm_isdst: INTEGER ;   (* DST.         [-1/0/1] *)
           tm_gmtoff: LONGINT ;  (* Seconds east of UTC.  *)
           tm_zone: ADDRESS ;    (* char * zone name      *)
        END ;

   timeb = RECORD
              time    : time_t ;
```

```
                    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 strtof(const char *restrict nptr, char **_Nullable restrict endptr)
*)
```

```
PROCEDURE strtof (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
```

```
           changed.  Only the super-user may change the  owner  of  a
           file.   The  owner  of  a file may change the group of the
           file to any group of which that owner is  a  member.   The
           super-user may change the group arbitrarily.

           If  the owner or group is specified as -1, then that ID is
           not changed.

           On success, zero is returned.  On error, -1  is  returned,
           and errno is set appropriately.
*)

PROCEDURE chown (filename: ADDRESS; uid, gid: INTEGER) : [ INTEGER ] ;


(*
   strlen - returns the length of string, a.
*)

PROCEDURE strlen (a: ADDRESS) : CSIZE_T ;


(*
   strcpy - copies string, src, into, dest.
            It returns dest.
*)

PROCEDURE strcpy (dest, src: ADDRESS) : [ ADDRESS ] ;


(*
   strncpy - copies string, src, into, dest, copying at most, n, bytes.
             It returns dest.
*)

PROCEDURE strncpy (dest, src: ADDRESS; n: CARDINAL) : [ ADDRESS ] ;


(*
   unlink - removes file and returns 0 if successful.
*)

PROCEDURE unlink (file: ADDRESS) : [ INTEGER ] ;


(*
   memcpy - copy memory area
```

```
   SYNOPSIS

   #include <string.h>

   void *memcpy(void *dest, const void *src, size_t n);
   It returns dest.
*)

PROCEDURE memcpy (dest, src: ADDRESS; size: CSIZE_T) : [ ADDRESS ] ;


(*
   memset - fill memory with a constant byte

   SYNOPSIS

   #include <string.h>

   void *memset(void *s, int c, size_t n);
   It returns s.
*)

PROCEDURE memset (s: ADDRESS; c: INTEGER; size: CSIZE_T) : [ ADDRESS ] ;


(*
   memmove - copy memory areas which may overlap

   SYNOPSIS

   #include <string.h>

   void *memmove(void *dest, const void *src, size_t n);
   It returns dest.
*)

PROCEDURE memmove (dest, src: ADDRESS; size: CSIZE_T) : [ ADDRESS ] ;


(*
   int printf(const char *format, ...);
*)

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

```
(*
   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 mo 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.
```

4.1.61 gm2-libs/libm

```
DEFINITION MODULE FOR "C" libm ;

(* Users are strongly advised to use MathLib0 or RealMath as calls
   to functions within these modules will generate inline code.
   This module is used by MathLib0 and RealMath when inline code cannot
   be generated.  *)

EXPORT UNQUALIFIED sin, sinl, sinf,
                   cos, cosl, cosf,
                   tan, tanl, tanf,
                   sqrt, sqrtl, sqrtf,
                   asin, asinl, asinf,
                   acos, acosl, acosf,
                   atan, atanl, atanf,
                   atan2, atan2l, atan2f,
                   exp, expl, expf,
                   log, logl, logf,
                   exp10, exp10l, exp10f,
                   pow, powl, powf,
                   floor, floorl, floorf,
                   ceil, ceill, ceilf ;

PROCEDURE sin (x: REAL) : REAL ;
PROCEDURE sinl (x: LONGREAL) : LONGREAL ;
PROCEDURE sinf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE cos (x: REAL) : REAL ;
PROCEDURE cosl (x: LONGREAL) : LONGREAL ;
PROCEDURE cosf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE tan (x: REAL) : REAL ;
PROCEDURE tanl (x: LONGREAL) : LONGREAL ;
PROCEDURE tanf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE sqrt (x: REAL) : REAL ;
PROCEDURE sqrtl (x: LONGREAL) : LONGREAL ;
PROCEDURE sqrtf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE asin (x: REAL) : REAL ;
PROCEDURE asinl (x: LONGREAL) : LONGREAL ;
PROCEDURE asinf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE acos (x: REAL) : REAL ;
PROCEDURE acosl (x: LONGREAL) : LONGREAL ;
PROCEDURE acosf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE atan (x: REAL) : REAL ;
PROCEDURE atanl (x: LONGREAL) : LONGREAL ;
PROCEDURE atanf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE atan2 (x, y: REAL) : REAL ;
PROCEDURE atan2l (x, y: LONGREAL) : LONGREAL ;
```

```
PROCEDURE atan2f (x, y: SHORTREAL) : SHORTREAL ;
PROCEDURE exp (x: REAL) : REAL ;
PROCEDURE expl (x: LONGREAL) : LONGREAL ;
PROCEDURE expf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE log (x: REAL) : REAL ;
PROCEDURE logl (x: LONGREAL) : LONGREAL ;
PROCEDURE logf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE exp10 (x: REAL) : REAL ;
PROCEDURE exp10l (x: LONGREAL) : LONGREAL ;
PROCEDURE exp10f (x: SHORTREAL) : SHORTREAL ;
PROCEDURE pow (x, y: REAL) : REAL ;
PROCEDURE powl (x, y: LONGREAL) : LONGREAL ;
PROCEDURE powf (x, y: SHORTREAL) : SHORTREAL ;
PROCEDURE floor (x: REAL) : REAL ;
PROCEDURE floorl (x: LONGREAL) : LONGREAL ;
PROCEDURE floorf (x: SHORTREAL) : SHORTREAL ;
PROCEDURE ceil (x: REAL) : REAL ;
PROCEDURE ceill (x: LONGREAL) : LONGREAL ;
PROCEDURE ceilf (x: SHORTREAL) : SHORTREAL ;

END libm.
```

4.1.62 gm2-libs/sckt

```
DEFINITION MODULE sckt ;

FROM SYSTEM IMPORT ADDRESS ;
EXPORT QUALIFIED tcpServerState,
                 tcpServerEstablish, tcpServerEstablishPort,
                 tcpServerAccept, getLocalIP,
                 tcpServerPortNo, tcpServerIP, tcpServerSocketFd,
                 tcpServerClientIP, tcpServerClientPortNo,
                 tcpClientState,
                 tcpClientSocket, tcpClientSocketIP, tcpClientConnect,
                 tcpClientPortNo, tcpClientIP, tcpClientSocketFd ;

TYPE
   tcpServerState = ADDRESS ;
   tcpClientState = ADDRESS ;


(*
   tcpServerEstablish - returns a tcpState containing the relevant
                        information about a socket declared to receive
                        tcp connections.
*)

PROCEDURE tcpServerEstablish () : tcpServerState ;


(*
   tcpServerEstablishPort - returns a tcpState containing the relevant
                            information about a socket declared to receive
                            tcp connections.  This method attempts to use
                            the port specified by the parameter.
*)

PROCEDURE tcpServerEstablishPort (port: CARDINAL) : tcpServerState ;


(*
   tcpServerAccept - returns a file descriptor once a client has connected and
                     been accepted.
*)

PROCEDURE tcpServerAccept (s: tcpServerState) : INTEGER ;


(*
```

```
   tcpServerPortNo - returns the portNo from structure, s.
*)

PROCEDURE tcpServerPortNo (s: tcpServerState) : CARDINAL ;


(*
   tcpSocketFd - returns the sockFd from structure, s.
*)

PROCEDURE tcpServerSocketFd (s: tcpServerState) : INTEGER ;


(*
   getLocalIP - returns the IP address of this machine.
*)

PROCEDURE getLocalIP (s: tcpServerState) : CARDINAL ;


(*
   tcpServerIP - returns the IP address from structure, s.
*)

PROCEDURE tcpServerIP (s: tcpServerState) : CARDINAL ;


(*
   tcpServerClientIP - returns the IP address of the client who
                       has connected to server, s.
*)

PROCEDURE tcpServerClientIP (s: tcpServerState) : CARDINAL ;


(*
   tcpServerClientPortNo - returns the port number of the client who
                           has connected to server, s.
*)

PROCEDURE tcpServerClientPortNo (s: tcpServerState) : CARDINAL ;


(*
   tcpClientSocket - returns a file descriptor (socket) which has
                     connected to, serverName:portNo.
*)
```

```
PROCEDURE tcpClientSocket (serverName: ADDRESS; portNo: CARDINAL) : tcpClientState ;


(*
   tcpClientSocketIP - returns a file descriptor (socket) which has
                       connected to, ip:portNo.
*)

PROCEDURE tcpClientSocketIP (ip: CARDINAL; portNo: CARDINAL) : tcpClientState ;


(*
   tcpClientConnect - returns the file descriptor associated with, s,
                      once a connect has been performed.
*)

PROCEDURE tcpClientConnect (s: tcpClientState) : INTEGER ;


(*
   tcpClientPortNo - returns the portNo from structure, s.
*)

PROCEDURE tcpClientPortNo (s: tcpClientState) : INTEGER ;


(*
   tcpClientSocketFd - returns the sockFd from structure, s.
*)

PROCEDURE tcpClientSocketFd (s: tcpClientState) : INTEGER ;


(*
   tcpClientIP - returns the IP address from structure, s.
*)

PROCEDURE tcpClientIP (s: tcpClientState) : CARDINAL ;


END sckt.
```

4.1.63 gm2-libs/termios

```
DEFINITION MODULE termios ;

FROM SYSTEM IMPORT ADDRESS ;

TYPE
   TERMIOS = ADDRESS ;

   ControlChar = (vintr, vquit, verase, vkill, veof, vtime, vmin,
                  vswtc, vstart, vstop, vsusp, veol, vreprint, vdiscard,
                  vwerase, vlnext, veol2) ;

   Flag = (
           (* input flag bits *)
           ignbrk, ibrkint, ignpar, iparmrk, inpck, istrip, inlcr,
           igncr, icrnl, iuclc, ixon, ixany, ixoff, imaxbel,
           (* output flag bits *)
           opost, olcuc, onlcr, ocrnl, onocr, onlret, ofill, ofdel,
           onl0, onl1, ocr0, ocr1, ocr2, ocr3,
           otab0, otab1, otab2, otab3, obs0, obs1, off0, off1, ovt0, ovt1,
           (* baud rate *)
           b0, b50, b75, b110, b135, b150, b200, b300, b600, b1200,
           b1800, b2400, b4800, b9600, b19200, b38400,
           b57600, b115200, b240400, b460800, b500000, b576000,
           b921600, b1000000, b1152000, b1500000, b2000000, b2500000,
           b3000000, b3500000, b4000000, maxbaud, crtscts,
           (* character size *)
           cs5, cs6, cs7, cs8, cstopb, cread, parenb, parodd, hupcl, clocal,
           (* local flags *)
           lisig, licanon, lxcase, lecho, lechoe, lechok, lechonl, lnoflsh,
           ltopstop, lechoctl, lechoprt, lechoke, lflusho, lpendin, liexten) ;


(*
   InitTermios - new data structure.
*)

PROCEDURE InitTermios () : TERMIOS ;


(*
   KillTermios - delete data structure.
*)

PROCEDURE KillTermios (t: TERMIOS) : TERMIOS ;
```

```
(*
   cfgetospeed - return output baud rate.
*)

PROCEDURE cfgetospeed (t: TERMIOS) : INTEGER ;


(*
   cfgetispeed - return input baud rate.
*)

PROCEDURE cfgetispeed (t: TERMIOS) : INTEGER ;


(*
   cfsetospeed - set output baud rate.
*)

PROCEDURE cfsetospeed (t: TERMIOS; b: CARDINAL) : INTEGER ;


(*
   cfsetispeed - set input baud rate.
*)

PROCEDURE cfsetispeed (t: TERMIOS; b: CARDINAL) : INTEGER ;


(*
   cfsetspeed - set input and output baud rate.
*)

PROCEDURE cfsetspeed (t: TERMIOS; b: CARDINAL) : INTEGER ;


(*
   tcgetattr - get state of, fd, into, t.
*)

PROCEDURE tcgetattr (fd: INTEGER; t: TERMIOS) : INTEGER ;


(*
   The following three functions return the different option values.
*)
```

```
PROCEDURE tcsnow () : INTEGER ;   (* alter fd now *)
PROCEDURE tcsdrain () : INTEGER ; (* alter when all output has been sent *)
PROCEDURE tcsflush () : INTEGER ; (* like drain, except discard any pending input *)


(*
   tcsetattr - set state of, fd, to, t, using option.
*)

PROCEDURE tcsetattr (fd: INTEGER; option: INTEGER; t: TERMIOS) : INTEGER ;


(*
   cfmakeraw - sets, t, to raw mode.
*)

PROCEDURE cfmakeraw (t: TERMIOS) ;


(*
   tcsendbreak - send zero bits for duration.
*)

PROCEDURE tcsendbreak (fd: INTEGER; duration: INTEGER) : INTEGER ;


(*
   tcdrain - waits for pending output to be written on, fd.
*)

PROCEDURE tcdrain (fd: INTEGER) : INTEGER ;


(*
   tcflushi - flush input.
*)

PROCEDURE tcflushi (fd: INTEGER) : INTEGER ;


(*
   tcflusho - flush output.
*)

PROCEDURE tcflusho (fd: INTEGER) : INTEGER ;
```

```
(*
   tcflushio - flush input and output.
*)

PROCEDURE tcflushio (fd: INTEGER) : INTEGER ;


(*
   tcflowoni - restart input on, fd.
*)

PROCEDURE tcflowoni (fd: INTEGER) : INTEGER ;


(*
   tcflowoffi - stop input on, fd.
*)

PROCEDURE tcflowoffi (fd: INTEGER) : INTEGER ;


(*
   tcflowono - restart output on, fd.
*)

PROCEDURE tcflowono (fd: INTEGER) : INTEGER ;


(*
   tcflowoffo - stop output on, fd.
*)

PROCEDURE tcflowoffo (fd: INTEGER) : INTEGER ;


(*
   GetFlag - sets a flag value from, t, in, b, and returns TRUE
             if, t, supports, f.
*)

PROCEDURE GetFlag (t: TERMIOS; f: Flag; VAR b: BOOLEAN) : BOOLEAN ;


(*
   SetFlag - sets a flag value in, t, to, b, and returns TRUE if
             this flag value is supported.
*)
```

```
PROCEDURE SetFlag (t: TERMIOS; f: Flag; b: BOOLEAN) : BOOLEAN ;


(*
   GetChar - sets a CHAR, ch, value from, t, and returns TRUE if
             this value is supported.
*)

PROCEDURE GetChar (t: TERMIOS; c: ControlChar; VAR ch: CHAR) : BOOLEAN ;


(*
   SetChar - sets a CHAR value in, t, and returns TRUE if, c,
             is supported.
*)

PROCEDURE SetChar (t: TERMIOS; c: ControlChar; ch: CHAR) : BOOLEAN ;


END termios.
```

4.1.64 gm2-libs/wrapc

```
DEFINITION MODULE wrapc ;

FROM SYSTEM IMPORT ADDRESS ;


(*
   strtime - returns the C string for the equivalent C asctime
             function.
*)

PROCEDURE strtime () : ADDRESS ;


(*
   filesize - assigns the size of a file, f, into low, high and
              returns zero if successful.
*)

PROCEDURE filesize (f: INTEGER; VAR low, high: CARDINAL) : INTEGER ;


(*
   fileinode - return the inode associated with file, f.
*)

PROCEDURE fileinode (f: INTEGER; VAR low, high: CARDINAL) : INTEGER ;


(*
   filemtime - returns the mtime of a file, f.
*)

PROCEDURE filemtime (f: INTEGER) : INTEGER ;


(*
   getrand - returns a random number between 0..n-1
*)

PROCEDURE getrand (n: INTEGER) : INTEGER ;


(*
   getusername - returns a C string describing the current user.
*)
```

```
PROCEDURE getusername () : ADDRESS ;


(*
   getnameuidgid - fills in the, uid, and, gid, which represents
                   user, name.
*)

PROCEDURE getnameuidgid (name: ADDRESS; VAR uid, gid: INTEGER) ;


(*
   in C these procedure functions are really macros, so we provide
   real C functions and let gm2 call these if the builtins
   are unavailable.
*)

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


(*
   isfinite - provide non builtin alternative to the gcc builtin isfinite.
              Returns 1 if x is finite and 0 if it is not.
*)

PROCEDURE isfinite (x: REAL) : INTEGER ;


(*
   isfinitef - provide non builtin alternative to the gcc builtin isfinite.
               Returns 1 if x is finite and 0 if it is not.
*)

PROCEDURE isfinitef (x: SHORTREAL) : INTEGER ;


(*
   isfinitel - provide non builtin alternative to the gcc builtin isfinite.
               Returns 1 if x is finite and 0 if it is not.
*)

PROCEDURE isfinitel (x: LONGREAL) : INTEGER ;
```

```
(*
   isnan - provide non builtin alternative to the gcc builtin isnan.
           Returns 1 if x is a NaN otherwise return 0.
*)

PROCEDURE isnan (x: REAL) : INTEGER ;


(*
   isnanf - provide non builtin alternative to the gcc builtin isnanf.
            Returns 1 if x is a NaN otherwise return 0.
*)

PROCEDURE isnanf (x: SHORTREAL) : INTEGER ;


(*
   isnanl - provide non builtin alternative to the gcc builtin isnanl.
            Returns 1 if x is a NaN otherwise return 0.
*)

PROCEDURE isnanl (x: LONGREAL) : INTEGER ;


(*
   SeekSet - return the system libc SEEK_SET value.
*)

PROCEDURE SeekSet () : INTEGER ;


(*
    SeekEnd - return the system libc SEEK_END value.
*)

PROCEDURE SeekEnd () : INTEGER ;


(*
   ReadOnly - return the system value of O_RDONLY.
*)

PROCEDURE ReadOnly () : BITSET ;


(*
   WriteOnly - return the system value of O_WRONLY.
```

```
*)

PROCEDURE WriteOnly () : BITSET ;


END wrapc.
```

4.2 PIM and Logitech 3.0 Compatible

These modules are provided to enable legacy Modula-2 applications to build with GNU Modula-2. It is advised that these module should not be used for new projects, maybe the ISO libraries or the native compiler PIM libraries (FIO) should be used instead.

Here is an outline of the module layering:

```
InOut  RealInOut  LongIO CardinalIO
    \     |        |      /
           Terminal
-----------------------------------
              |
           Termbase
           /      \
    Keyboard      Display
```

Above the line are user level PIM [234] and Logitech 3.0 compatible modules. Below the line Logitech 3.0 advised that these modules should be considered part of the runtime system. The libraries do not provide all the features found in the Logitech libraries as a number of these features were MS-DOS related. Essentially the basic input/output, file system, string manipulation and conversion routines are provided. Access to DOSCALL, graphics, time and date are not as these were constrained by the limitations of MS-DOS.

The following libraries are contained within the base GNU Modula-2 libraries and are also Logitech-3.0 compatible: See Section 4.1.2 [gm2-libs/ASCII], page 87, See Section 4.1.42 [gm2-libs/Storage], page 172, and See Section 4.1.26 [gm2-libs/MathLib0], page 140. These libraries are always available for any dialect of the language (although their implementation and behaviour might differ, for example Storage ISO and PIM).

The following libraries are Logitech-3.0 compatible but fall outside the base GNU Modula-2 libraries.

4.2.1 gm2-libs-log/BitBlockOps

```
DEFINITION MODULE BitBlockOps ;


FROM SYSTEM IMPORT ADDRESS ;


(*
   BlockAnd - performs a bitwise AND on blocks
              [dest..dest+size-1] := [dest..dest+size-1] AND
                                     [src..src+size-1]
*)

PROCEDURE BlockAnd (dest, src: ADDRESS; size: CARDINAL) ;
```

```
(*
   BlockOr - performs a bitwise OR on blocks
             [dest..dest+size-1] := [dest..dest+size-1] OR
                                    [src..src+size-1]
*)

PROCEDURE BlockOr (dest, src: ADDRESS; size: CARDINAL) ;


(*
   BlockXor - performs a bitwise XOR on blocks
              [dest..dest+size-1] := [dest..dest+size-1] XOR
                                     [src..src+size-1]
*)

PROCEDURE BlockXor (dest, src: ADDRESS; size: CARDINAL) ;


(*
   BlockNot - performs a bitsize NOT on the block as defined
              by:  [dest..dest+size-1]
*)

PROCEDURE BlockNot (dest: ADDRESS; size: CARDINAL) ;


(*
   BlockShr - performs a block shift right of, count, bits.
              Where the block is defined as:
              [dest..dest+size-1].
              The block is considered to be an ARRAY OF BYTEs
              which is shifted, bit at a time over each byte in
              turn.  The left most byte is considered the byte
              located at the lowest address.
              If you require an endianness SHIFT use
              the SYSTEM.SHIFT procedure and declare the
              block as a POINTER TO set type.
*)

PROCEDURE BlockShr (dest: ADDRESS; size, count: CARDINAL) ;


(*
   BlockShl - performs a block shift left of, count, bits.
              Where the block is defined as:
              [dest..dest+size-1].
              The block is considered to be an ARRAY OF BYTEs
```

```
              which is shifted, bit at a time over each byte in
              turn.  The left most byte is considered the byte
              located at the lowest address.
              If you require an endianness SHIFT use
              the SYSTEM.SHIFT procedure and declare the
              block as a POINTER TO set type.
*)

PROCEDURE BlockShl (dest: ADDRESS; size, count: CARDINAL) ;


(*
   BlockRor - performs a block rotate right of, count, bits.
              Where the block is defined as:
              [dest..dest+size-1].
              The block is considered to be an ARRAY OF BYTEs
              which is rotated, bit at a time over each byte in
              turn.  The left most byte is considered the byte
              located at the lowest address.
              If you require an endianness ROTATE use
              the SYSTEM.ROTATE procedure and declare the
              block as a POINTER TO set type.
*)

PROCEDURE BlockRor (dest: ADDRESS; size, count: CARDINAL) ;


(*
   BlockRol - performs a block rotate left of, count, bits.
              Where the block is defined as:
              [dest..dest+size-1].
              The block is considered to be an ARRAY OF BYTEs
              which is rotated, bit at a time over each byte in
              turn.  The left most byte is considered the byte
              located at the lowest address.
              If you require an endianness ROTATE use
              the SYSTEM.ROTATE procedure and declare the
              block as a POINTER TO set type.
*)

PROCEDURE BlockRol (dest: ADDRESS; size, count: CARDINAL) ;


END BitBlockOps.
```

4.2.2 gm2-libs-log/BitByteOps

```
DEFINITION MODULE BitByteOps ;

FROM SYSTEM IMPORT BYTE ;


(*
   GetBits - returns the bits firstBit..lastBit from source.
             Bit 0 of byte maps onto the firstBit of source.
*)

PROCEDURE GetBits (source: BYTE; firstBit, lastBit: CARDINAL) : BYTE ;


(*
   SetBits - sets bits in, byte, starting at, firstBit, and ending at,
             lastBit, with, pattern.  The bit zero of, pattern, will
             be placed into, byte, at position, firstBit.
*)

PROCEDURE SetBits (VAR byte: BYTE; firstBit, lastBit: CARDINAL;
                   pattern: BYTE) ;


(*
   ByteAnd - returns a bitwise (left AND right)
*)

PROCEDURE ByteAnd (left, right: BYTE) : BYTE ;


(*
   ByteOr - returns a bitwise (left OR right)
*)

PROCEDURE ByteOr (left, right: BYTE) : BYTE ;


(*
   ByteXor - returns a bitwise (left XOR right)
*)

PROCEDURE ByteXor (left, right: BYTE) : BYTE ;


(*
```

```
   ByteNot - returns a byte with all bits inverted.
*)

PROCEDURE ByteNot (byte: BYTE) : BYTE ;


(*
   ByteShr - returns a, byte, which has been shifted, count
             bits to the right.
*)

PROCEDURE ByteShr (byte: BYTE; count: CARDINAL) : BYTE ;


(*
   ByteShl - returns a, byte, which has been shifted, count
             bits to the left.
*)

PROCEDURE ByteShl (byte: BYTE; count: CARDINAL) : BYTE ;


(*
   ByteSar - shift byte arthemetic right.  Preserves the top
             end bit and as the value is shifted right.
*)

PROCEDURE ByteSar (byte: BYTE; count: CARDINAL) : BYTE ;


(*
   ByteRor - returns a, byte, which has been rotated, count
             bits to the right.
*)

PROCEDURE ByteRor (byte: BYTE; count: CARDINAL) : BYTE ;


(*
   ByteRol - returns a, byte, which has been rotated, count
             bits to the left.
*)

PROCEDURE ByteRol (byte: BYTE; count: CARDINAL) : BYTE ;


(*
```

```
   HighNibble - returns the top nibble only from, byte.
                The top nibble of, byte, is extracted and
                returned in the bottom nibble of the return
                value.
*)

PROCEDURE HighNibble (byte: BYTE) : BYTE ;


(*
   LowNibble - returns the low nibble only from, byte.
               The top nibble is replaced by zeros.
*)

PROCEDURE LowNibble (byte: BYTE) : BYTE ;


(*
   Swap - swaps the low and high nibbles in the, byte.
*)

PROCEDURE Swap (byte: BYTE) : BYTE ;


END BitByteOps.
```

4.2.3 gm2-libs-log/BitWordOps

```
DEFINITION MODULE BitWordOps ;

FROM SYSTEM IMPORT WORD ;


(*
   GetBits - returns the bits firstBit..lastBit from source.
             Bit 0 of word maps onto the firstBit of source.
*)

PROCEDURE GetBits (source: WORD; firstBit, lastBit: CARDINAL) : WORD ;


(*
   SetBits - sets bits in, word, starting at, firstBit, and ending at,
             lastBit, with, pattern.  The bit zero of, pattern, will
             be placed into, word, at position, firstBit.
*)

PROCEDURE SetBits (VAR word: WORD; firstBit, lastBit: CARDINAL;
                   pattern: WORD) ;


(*
   WordAnd - returns a bitwise (left AND right)
*)

PROCEDURE WordAnd (left, right: WORD) : WORD ;


(*
   WordOr - returns a bitwise (left OR right)
*)

PROCEDURE WordOr (left, right: WORD) : WORD ;


(*
   WordXor - returns a bitwise (left XOR right)
*)

PROCEDURE WordXor (left, right: WORD) : WORD ;


(*
```

```
   WordNot - returns a word with all bits inverted.
*)

PROCEDURE WordNot (word: WORD) : WORD ;


(*
   WordShr - returns a, word, which has been shifted, count
             bits to the right.
*)

PROCEDURE WordShr (word: WORD; count: CARDINAL) : WORD ;


(*
   WordShl - returns a, word, which has been shifted, count
             bits to the left.
*)

PROCEDURE WordShl (word: WORD; count: CARDINAL) : WORD ;


(*
   WordSar - shift word arthemetic right.  Preserves the top
             end bit and as the value is shifted right.
*)

PROCEDURE WordSar (word: WORD; count: CARDINAL) : WORD ;


(*
   WordRor - returns a, word, which has been rotated, count
             bits to the right.
*)

PROCEDURE WordRor (word: WORD; count: CARDINAL) : WORD ;


(*
   WordRol - returns a, word, which has been rotated, count
             bits to the left.
*)

PROCEDURE WordRol (word: WORD; count: CARDINAL) : WORD ;


(*
```

```
   HighByte - returns the top byte only from, word.
              The byte is returned in the bottom byte
              in the return value.
*)

PROCEDURE HighByte (word: WORD) : WORD ;


(*
   LowByte - returns the low byte only from, word.
             The byte is returned in the bottom byte
             in the return value.
*)

PROCEDURE LowByte (word: WORD) : WORD ;


(*
   Swap - byte flips the contents of word.
*)

PROCEDURE Swap (word: WORD) : WORD ;


END BitWordOps.
```

4.2.4 gm2-libs-log/BlockOps

```
DEFINITION MODULE BlockOps ;

FROM SYSTEM IMPORT ADDRESS ;


(*
   MoveBlockForward - moves, n, bytes from, src, to, dest.
                      Starts copying from src and keep copying
                      until, n, bytes have been copied.
*)

PROCEDURE BlockMoveForward (dest, src: ADDRESS; n: CARDINAL) ;


(*
   MoveBlockBackward - moves, n, bytes from, src, to, dest.
                       Starts copying from src+n and keeps copying
                       until, n, bytes have been copied.
                       The last datum to be copied will be the byte
                       at address, src.
*)

PROCEDURE BlockMoveBackward (dest, src: ADDRESS; n: CARDINAL) ;


(*
   BlockClear - fills, block..block+n-1, with zeros.
*)

PROCEDURE BlockClear (block: ADDRESS; n: CARDINAL) ;


(*
   BlockSet - fills, n, bytes starting at, block, with a pattern
              defined at address pattern..pattern+patternSize-1.
*)

PROCEDURE BlockSet (block: ADDRESS; n: CARDINAL;
                    pattern: ADDRESS; patternSize: CARDINAL) ;


(*
   BlockEqual - returns TRUE if the blocks defined, a..a+n-1, and,
                b..b+n-1 contain the same bytes.
*)
```

```
PROCEDURE BlockEqual (a, b: ADDRESS; n: CARDINAL) : BOOLEAN ;


(*
   BlockPosition - searches for a pattern as defined by
                   pattern..patternSize-1 in the block,
                   block..block+blockSize-1.  It returns
                   the offset from block indicating the
                   first occurence of, pattern.
                   MAX(CARDINAL) is returned if no match
                   is detected.
*)

PROCEDURE BlockPosition (block: ADDRESS; blockSize: CARDINAL;
                         pattern: ADDRESS; patternSize: CARDINAL) : CARDINAL ;


END BlockOps.
```

4.2.5 gm2-libs-log/Break

```
DEFINITION MODULE Break ;


EXPORT QUALIFIED EnableBreak, DisableBreak, InstallBreak, UnInstallBreak ;


(*
   EnableBreak - enable the current break handler.
*)

PROCEDURE EnableBreak ;


(*
   DisableBreak - disable the current break handler (and all
                  installed handlers).
*)

PROCEDURE DisableBreak ;


(*
   InstallBreak - installs a procedure, p, to be invoked when
                  a ctrl-c is caught. Any number of these
                  procedures may be stacked. Only the top
                  procedure is run when ctrl-c is caught.
*)

PROCEDURE InstallBreak (p: PROC) ;


(*
   UnInstallBreak - pops the break handler stack.
*)

PROCEDURE UnInstallBreak ;


END Break.
```

4.2.6 gm2-libs-log/CardinalIO

```
DEFINITION MODULE CardinalIO ;

EXPORT QUALIFIED Done,
                 ReadCardinal, WriteCardinal, ReadHex, WriteHex,
                 ReadLongCardinal, WriteLongCardinal, ReadLongHex,
                 WriteLongHex,
                 ReadShortCardinal, WriteShortCardinal, ReadShortHex,
                 WriteShortHex ;


VAR
   Done: BOOLEAN ;


(*
   ReadCardinal - read an unsigned decimal number from the terminal.
                  The read continues until a space, newline, esc or
                  end of file is reached.
*)

PROCEDURE ReadCardinal (VAR c: CARDINAL) ;


(*
   WriteCardinal - writes the value, c, to the terminal and ensures
                   that at least, n, characters are written. The number
                   will be padded out by preceeding spaces if necessary.
*)

PROCEDURE WriteCardinal (c: CARDINAL; n: CARDINAL) ;


(*
   ReadHex - reads in an unsigned hexadecimal number from the terminal.
             The read continues until a space, newline, esc or
             end of file is reached.
*)

PROCEDURE ReadHex (VAR c: CARDINAL) ;


(*
   WriteHex - writes out a CARDINAL, c, in hexadecimal format padding
              with, n, characters (leading with '0')
*)
```

```
PROCEDURE WriteHex (c: CARDINAL; n: CARDINAL) ;


(*
   ReadLongCardinal - read an unsigned decimal number from the terminal.
                      The read continues until a space, newline, esc or
                      end of file is reached.
*)

PROCEDURE ReadLongCardinal (VAR c: LONGCARD) ;


(*
   WriteLongCardinal - writes the value, c, to the terminal and ensures
                       that at least, n, characters are written. The number
                       will be padded out by preceeding spaces if necessary.
*)

PROCEDURE WriteLongCardinal (c: LONGCARD; n: CARDINAL) ;


(*
   ReadLongHex - reads in an unsigned hexadecimal number from the terminal.
                 The read continues until a space, newline, esc or
                 end of file is reached.
*)

PROCEDURE ReadLongHex (VAR c: LONGCARD) ;


(*
   WriteLongHex - writes out a LONGCARD, c, in hexadecimal format padding
                  with, n, characters (leading with '0')
*)

PROCEDURE WriteLongHex (c: LONGCARD; n: CARDINAL) ;


(*
   WriteShortCardinal - writes the value, c, to the terminal and ensures
                       that at least, n, characters are written. The number
                       will be padded out by preceeding spaces if necessary.
*)

PROCEDURE WriteShortCardinal (c: SHORTCARD; n: CARDINAL) ;
```

```
(*
   ReadShortCardinal - read an unsigned decimal number from the terminal.
                       The read continues until a space, newline, esc or
                       end of file is reached.
*)

PROCEDURE ReadShortCardinal (VAR c: SHORTCARD) ;


(*
   ReadShortHex - reads in an unsigned hexadecimal number from the terminal.
                  The read continues until a space, newline, esc or
                  end of file is reached.
*)

PROCEDURE ReadShortHex (VAR c: SHORTCARD) ;


(*
   WriteShortHex - writes out a SHORTCARD, c, in hexadecimal format padding
                   with, n, characters (leading with '0')
*)

PROCEDURE WriteShortHex (c: SHORTCARD; n: CARDINAL) ;


END CardinalIO.
```

4.2.7 gm2-libs-log/Conversions

```
DEFINITION MODULE Conversions ;

EXPORT QUALIFIED ConvertOctal, ConvertHex, ConvertCardinal,
                 ConvertInteger, ConvertLongInt, ConvertShortInt ;

(*
   ConvertOctal - converts a CARDINAL, num, into an octal/hex/decimal
                  string and right justifies the string. It adds
                  spaces rather than '0' to pad out the string
                  to len characters.

                  If the length of str is < num then the number is
                  truncated on the right.
*)

PROCEDURE ConvertOctal    (num, len: CARDINAL; VAR str: ARRAY OF CHAR) ;
PROCEDURE ConvertHex      (num, len: CARDINAL; VAR str: ARRAY OF CHAR) ;
PROCEDURE ConvertCardinal (num, len: CARDINAL; VAR str: ARRAY OF CHAR) ;

(*
   The INTEGER counterparts will add a '-' if, num, is <0
*)

PROCEDURE ConvertInteger  (num: INTEGER; len: CARDINAL; VAR str: ARRAY OF CHAR) ;
PROCEDURE ConvertLongInt  (num: LONGINT; len: CARDINAL; VAR str: ARRAY OF CHAR) ;
PROCEDURE ConvertShortInt (num: SHORTINT; len: CARDINAL; VAR str: ARRAY OF CHAR) ;


END Conversions.
```

4.2.8 gm2-libs-log/DebugPMD

```
DEFINITION MODULE DebugPMD ;

END DebugPMD.
```

4.2.9 gm2-libs-log/DebugTrace

```
DEFINITION MODULE DebugTrace ;

END DebugTrace.
```

4.2.10 gm2-libs-log/Delay

```
DEFINITION MODULE Delay ;

EXPORT QUALIFIED Delay ;


(*
   milliSec - delays the program by approximately, milliSec, milliseconds.
*)

PROCEDURE Delay (milliSec: INTEGER) ;


END Delay.
```

4.2.11 gm2-libs-log/Display

```
DEFINITION MODULE Display ;

EXPORT QUALIFIED Write ;


(*
   Write - display a character to the stdout.
           ASCII.EOL moves to the beginning of the next line.
           ASCII.del erases the character to the left of the cursor.
*)

PROCEDURE Write (ch: CHAR) ;


END Display.
```

4.2.12 gm2-libs-log/ErrorCode

```
DEFINITION MODULE ErrorCode ;

EXPORT QUALIFIED SetErrorCode, GetErrorCode, ExitToOS ;


(*
   SetErrorCode - sets the exit value which will be used if
                  the application terminates normally.
*)

PROCEDURE SetErrorCode (value: INTEGER) ;


(*
   GetErrorCode - returns the current value to be used upon
                  application termination.
*)

PROCEDURE GetErrorCode (VAR value: INTEGER) ;


(*
   ExitToOS - terminate the application and exit returning
              the last value set by SetErrorCode to the OS.
*)

PROCEDURE ExitToOS ;


END ErrorCode.
```

4.2.13 gm2-libs-log/FileSystem

```
DEFINITION MODULE FileSystem ;

(*  Use this module sparingly, FIO or the ISO file modules have a
    much cleaner interface.  *)

FROM SYSTEM IMPORT WORD, BYTE, ADDRESS ;
IMPORT FIO ;
FROM DynamicStrings IMPORT String ;

EXPORT QUALIFIED File, Response, Flag, FlagSet,

                 Create, Close, Lookup, Rename, Delete,
                 SetRead, SetWrite, SetModify, SetOpen,
                 Doio, SetPos, GetPos, Length, Reset,

                 ReadWord, ReadChar, ReadByte, ReadNBytes,
                 WriteWord, WriteChar, WriteByte, WriteNBytes ;

TYPE
   File = RECORD
             res     : Response ;
             flags   : FlagSet ;
             eof     : BOOLEAN ;
             lastWord: WORD ;
             lastByte: BYTE ;
             fio     : FIO.File ;
             highpos,
             lowpos  : CARDINAL ;
             name    : String ;
          END ;

   Flag = (
           read,        (* read access mode *)
           write,       (* write access mode *)
           modify,
           truncate,    (* truncate file when closed *)
           again,       (* reread the last character *)
           temporary,   (* file is temporary *)
           opened       (* file has been opened *)
          );

   FlagSet = SET OF Flag;

   Response = (done, notdone, notsupported, callerror,
               unknownfile, paramerror, toomanyfiles,
```

```
                userdeverror) ;

   Command = (create, close, lookup, rename, delete,
              setread, setwrite, setmodify, setopen,
              doio, setpos, getpos, length) ;


(*
   Create - creates a temporary file. To make the file perminant
            the file must be renamed.
*)

PROCEDURE Create (VAR f: File) ;


(*
   Close - closes an open file.
*)

PROCEDURE Close (f: File) ;


(*
   Lookup - looks for a file, filename. If the file is found
            then, f, is opened. If it is not found and, newFile,
            is TRUE then a new file is created and attached to, f.
            If, newFile, is FALSE and no file was found then f.res
            is set to notdone.
*)

PROCEDURE Lookup (VAR f: File; filename: ARRAY OF CHAR; newFile: BOOLEAN) ;


(*
   Rename - rename a file and change a temporary file to a permanent
            file. f.res is set appropriately.
*)

PROCEDURE Rename (VAR f: File; newname: ARRAY OF CHAR) ;


(*
   Delete - deletes a file, name, and sets the f.res field.
            f.res is set appropriately.
*)

PROCEDURE Delete (name: ARRAY OF CHAR; VAR f: File) ;
```

```
(*
   ReadWord - reads a WORD, w, from file, f.
              f.res is set appropriately.
*)

PROCEDURE ReadWord (VAR f: File; VAR w: WORD) ;


(*
   WriteWord - writes one word to a file, f.
               f.res is set appropriately.
*)

PROCEDURE WriteWord (VAR f: File; w: WORD) ;


(*
   ReadChar - reads one character from a file, f.
*)

PROCEDURE ReadChar (VAR f: File; VAR ch: CHAR) ;


(*
   WriteChar - writes a character, ch, to a file, f.
               f.res is set appropriately.
*)

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


(*
   ReadByte - reads a BYTE, b, from file, f.
              f.res is set appropriately.
*)

PROCEDURE ReadByte (VAR f: File; VAR b: BYTE) ;


(*
   WriteByte - writes one BYTE, b, to a file, f.
               f.res is set appropriately.
*)

PROCEDURE WriteByte (VAR f: File; b: BYTE) ;
```

```
(*
   ReadNBytes - reads a sequence of bytes from a file, f.
*)

PROCEDURE ReadNBytes (VAR f: File; a: ADDRESS; amount: CARDINAL;
                      VAR actuallyRead: CARDINAL) ;


(*
   WriteNBytes - writes a sequence of bytes to file, f.
*)

PROCEDURE WriteNBytes (VAR f: File; a: ADDRESS; amount: CARDINAL;
                       VAR actuallyWritten: CARDINAL) ;


(*
   Again - returns the last character read to the internal buffer
           so that it can be read again.
*)

PROCEDURE Again (VAR f: File) ;


(*
   SetRead - puts the file, f, into the read state.
             The file position is unchanged.
*)

PROCEDURE SetRead (VAR f: File) ;


(*
   SetWrite - puts the file, f, into the write state.
              The file position is unchanged.
*)

PROCEDURE SetWrite (VAR f: File) ;


(*
   SetModify - puts the file, f, into the modify state.
               The file position is unchanged but the file can be
               read and written.
*)
```

```
PROCEDURE SetModify (VAR f: File) ;


(*
   SetOpen - places a file, f, into the open state. The file may
             have been in the read/write/modify state before and
             in which case the previous buffer contents are flushed
             and the file state is reset to open. The position is
             unaltered.
*)

PROCEDURE SetOpen (VAR f: File) ;


(*
   Reset - places a file, f, into the open state and reset the
           position to the start of the file.
*)

PROCEDURE Reset (VAR f: File) ;


(*
   SetPos - lseek to a position within a file.
*)

PROCEDURE SetPos (VAR f: File; high, low: CARDINAL) ;


(*
   GetPos - return the position within a file.
*)

PROCEDURE GetPos (VAR f: File; VAR high, low: CARDINAL) ;


(*
   Length - returns the length of file, in, high, and, low.
*)

PROCEDURE Length (VAR f: File; VAR high, low: CARDINAL) ;


(*
   Doio - effectively flushes a file in write mode, rereads the
          current buffer from disk if in read mode and writes
```

```
          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.
```

4.2.14 gm2-libs-log/FloatingUtilities

```
DEFINITION MODULE FloatingUtilities ;

EXPORT QUALIFIED Frac, Round, Float, Trunc,
                 Fracl, Roundl, Floatl, Truncl ;


(*
   Frac - returns the fractional component of, r.
*)

PROCEDURE Frac (r: REAL) : REAL ;


(*
   Int - returns the integer part of r. It rounds the value towards zero.
*)

PROCEDURE Int (r: REAL) : INTEGER ;


(*
   Round - returns the number rounded to the nearest integer.
*)

PROCEDURE Round (r: REAL) : INTEGER ;


(*
   Float - returns a REAL value corresponding to, i.
*)

PROCEDURE Float (i: INTEGER) : REAL ;


(*
   Trunc - round to the nearest integer not larger in absolute
           value.
*)

PROCEDURE Trunc (r: REAL) : INTEGER ;


(*
   Fracl - returns the fractional component of, r.
*)
```

```
PROCEDURE Fracl (r: LONGREAL) : LONGREAL ;


(*
   Intl - returns the integer part of r. It rounds the value towards zero.
*)

PROCEDURE Intl (r: LONGREAL) : LONGINT ;


(*
   Roundl - returns the number rounded to the nearest integer.
*)

PROCEDURE Roundl (r: LONGREAL) : LONGINT ;


(*
   Floatl - returns a REAL value corresponding to, i.
*)

PROCEDURE Floatl (i: INTEGER) : LONGREAL ;


(*
   Truncl - round to the nearest integer not larger in absolute
            value.
*)

PROCEDURE Truncl (r: LONGREAL) : LONGINT ;


END FloatingUtilities.
```

4.2.15 gm2-libs-log/InOut

```
DEFINITION MODULE InOut ;

IMPORT ASCII ;
FROM DynamicStrings IMPORT String ;
EXPORT QUALIFIED EOL, Done, termCH, OpenInput, OpenOutput,
                 CloseInput, CloseOutput,
                 Read, ReadString, ReadInt, ReadCard,
                 Write, WriteLn, WriteString, WriteInt, WriteCard,
                 WriteOct, WriteHex,
                 ReadS, WriteS ;

CONST
   EOL = ASCII.EOL ;

VAR
   Done  : BOOLEAN ;
   termCH: CHAR ;


(*
   OpenInput - reads a string from stdin as the filename for reading.
               If the filename ends with '.' then it appends the defext
               extension. The global variable Done is set if all
               was successful.
*)

PROCEDURE OpenInput (defext: ARRAY OF CHAR) ;


(*
   CloseInput - closes an opened input file and returns input back to
                StdIn.
*)

PROCEDURE CloseInput ;


(*
   OpenOutput - reads a string from stdin as the filename for writing.
                If the filename ends with '.' then it appends the defext
                extension. The global variable Done is set if all
                was successful.
*)

PROCEDURE OpenOutput (defext: ARRAY OF CHAR) ;
```

```
(*
   CloseOutput - closes an opened output file and returns output back to
                 StdOut.
*)

PROCEDURE CloseOutput ;


(*
   Read - reads a single character from the current input file.
          Done is set to FALSE if end of file is reached or an
          error occurs.
*)

PROCEDURE Read (VAR ch: CHAR) ;


(*
   ReadString - reads a sequence of characters. Leading white space
                is ignored and the string is terminated with a character
                <= ' '
*)

PROCEDURE ReadString (VAR s: ARRAY OF CHAR) ;


(*
   WriteString - writes a string to the output file.
*)

PROCEDURE WriteString (s: ARRAY OF CHAR) ;


(*
   Write - writes out a single character, ch, to the current output file.
*)

PROCEDURE Write (ch: CHAR) ;


(*
   WriteLn - writes a newline to the output file.
*)

PROCEDURE WriteLn ;
```

```
(*
   ReadInt - reads a string and converts it into an INTEGER, x.
             Done is set if an INTEGER is read.
*)

PROCEDURE ReadInt (VAR x: INTEGER) ;


(*
   ReadInt - reads a string and converts it into an INTEGER, x.
             Done is set if an INTEGER is read.
*)

PROCEDURE ReadCard (VAR x: CARDINAL) ;


(*
   WriteCard - writes the CARDINAL, x, to the output file. It ensures
               that the number occupies, n, characters. Leading spaces
               are added if required.
*)

PROCEDURE WriteCard (x, n: CARDINAL) ;


(*
   WriteInt - writes the INTEGER, x, to the output file. It ensures
              that the number occupies, n, characters. Leading spaces
              are added if required.
*)

PROCEDURE WriteInt (x: INTEGER; n: CARDINAL) ;


(*
   WriteOct - writes the CARDINAL, x, to the output file in octal.
              It ensures that the number occupies, n, characters.
              Leading spaces are added if required.
*)

PROCEDURE WriteOct (x, n: CARDINAL) ;


(*
   WriteHex - writes the CARDINAL, x, to the output file in hexadecimal.
```

```
              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.
```

4.2.16 gm2-libs-log/Keyboard

```
DEFINITION MODULE Keyboard ;

EXPORT QUALIFIED Read, KeyPressed ;


(*
   Read - reads a character from StdIn. If necessary it will wait
          for a key to become present on StdIn.
*)

PROCEDURE Read (VAR ch: CHAR) ;


(*
   KeyPressed - returns TRUE if a character can be read from StdIn
                without blocking the caller.
*)

PROCEDURE KeyPressed () : BOOLEAN ;


END Keyboard.
```

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.
```

4.2.19 gm2-libs-log/Random

```
DEFINITION MODULE Random ;

FROM SYSTEM IMPORT BYTE ;
EXPORT QUALIFIED Randomize, RandomInit, RandomBytes, RandomCard, RandomInt, RandomReal, RandomLongReal ;


(*
   Randomize - initialize the random number generator with a seed
               based on the microseconds.
*)

PROCEDURE Randomize ;


(*
   RandomInit - initialize the random number generator with value, seed.
*)

PROCEDURE RandomInit (seed: CARDINAL) ;


(*
   RandomBytes - fills in an array with random values.
*)

PROCEDURE RandomBytes (VAR a: ARRAY OF BYTE) ;


(*
   RandomInt - return an INTEGER in the range 0..bound-1
*)

PROCEDURE RandomInt (bound: INTEGER) : INTEGER ;


(*
   RandomCard - return a CARDINAL in the range 0..bound-1
*)

PROCEDURE RandomCard (bound: CARDINAL) : CARDINAL ;


(*
   RandomReal - return a REAL number in the range 0.0..1.0
*)
```

```
PROCEDURE RandomReal () : REAL ;


(*
   RandomLongReal - return a LONGREAL number in the range 0.0..1.0
*)

PROCEDURE RandomLongReal () : LONGREAL ;


END Random.
```

4.2.20 gm2-libs-log/RealConversions

```
DEFINITION MODULE RealConversions ;

EXPORT QUALIFIED SetNoOfExponentDigits,
                 RealToString, StringToReal,
                 LongRealToString, StringToLongReal ;


(*
   SetNoOfExponentDigits - sets the number of exponent digits to be
                           used during future calls of LongRealToString
                           and RealToString providing that the width
                           is sufficient.
                           If this value is set to 0 (the default) then
                           the number digits used is the minimum necessary.
*)

PROCEDURE SetNoOfExponentDigits (places: CARDINAL) ;


(*
   RealToString - converts a real, r, into a right justified string, str.
                  The number of digits to the right of the decimal point
                  is given in, digits.  The value, width, represents the
                  maximum number of characters to be used in the string,
                  str.

                  If digits is negative then exponent notation is used
                  whereas if digits is positive then fixed point notation
                  is used.

                  If, r, is less than 0.0 then a '-' preceeds the value,
                  str.  However, if, r, is >= 0.0 a '+' is not added.

                  If the conversion of, r, to a string requires more
                  than, width, characters then the string, str, is set
                  to a nul string and, ok is assigned FALSE.

                  For fixed point notation the minimum width required is
                  ABS(width)+8

                  For exponent notation the minimum width required is
                  ABS(digits)+2+log10(magnitude).

                  if r is a NaN then the string 'nan' is returned formatted and
                  ok will be FALSE.
```

```
*)

PROCEDURE RealToString (r: REAL; digits, width: INTEGER;
                        VAR str: ARRAY OF CHAR; VAR ok: BOOLEAN) ;


(*
   LongRealToString - converts a real, r, into a right justified string, str.
                      The number of digits to the right of the decimal point
                      is given in, digits. The value, width, represents the
                      maximum number of characters to be used in the string,
                      str.

                      If digits is negative then exponent notation is used
                      whereas if digits is positive then fixed point notation
                      is used.

                      If, r, is less than 0.0 then a '-' preceeds the value,
                      str. However, if, r, is >= 0.0 a '+' is not added.

                      If the conversion of, r, to a string requires more
                      than, width, characters then the string, str, is set
                      to a nul string and, ok is assigned FALSE.

                      For fixed point notation the minimum width required is
                      ABS(width)+8

                      For exponent notation the minimum width required is
                      ABS(digits)+2+log10(magnitude).

                      Examples:
                      RealToString(100.0, 10, 10, a, ok)       ->  '100.000000'
                      RealToString(100.0, -5, 12, a, ok)       ->  '  1.00000E+2'

                      RealToString(123.456789, 10, 10, a, ok)  ->  '123.456789'
                      RealToString(123.456789, -5, 13, a, ok)  ->  '    1.23456E+2'

                      RealToString(123.456789, -2, 15, a, ok)  ->  '          1.23E+2'

                      if r is a NaN then the string 'nan' is returned formatted and
                      ok will be FALSE.
*)

PROCEDURE LongRealToString (r: LONGREAL; digits, width: INTEGER;
                            VAR str: ARRAY OF CHAR; VAR ok: BOOLEAN) ;
```

```
(*
   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.
```

4.2.22 gm2-libs-log/Strings

```
DEFINITION MODULE Strings ;

EXPORT QUALIFIED Assign, Insert, Delete, Pos, Copy, ConCat, Length,
                 CompareStr ;

(*
   Assign - dest := source.
*)

PROCEDURE Assign (VAR dest: ARRAY OF CHAR; source: ARRAY OF CHAR) ;


(*
   Insert - insert the string, substr, into str at position, index.
            substr, is added to the end of, str, if, index >= length(str)
*)

PROCEDURE Insert (substr: ARRAY OF CHAR; VAR str: ARRAY OF CHAR;
                  index: CARDINAL) ;


(*
   Delete - delete len characters from, str, starting at, index.
*)

PROCEDURE Delete (VAR str: ARRAY OF CHAR; index: CARDINAL; length: CARDINAL) ;


(*
   Pos - return the first position of, substr, in, str.
*)

PROCEDURE Pos (substr, str: ARRAY OF CHAR) : CARDINAL ;


(*
   Copy - copy at most, length, characters in, substr, to, str,
          starting at position, index.
*)

PROCEDURE Copy (str: ARRAY OF CHAR;
                index, length: CARDINAL; VAR result: ARRAY OF CHAR) ;

(*
   ConCat - concatenates two strings, s1, and, s2
```

```
             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.
```

4.2.24 gm2-libs-log/Terminal

```
DEFINITION MODULE Terminal ;

(*
   It provides simple terminal input output
   routines which all utilize the TermBase module.
*)

EXPORT QUALIFIED Read, KeyPressed, ReadAgain, ReadString, Write,
                 WriteString, WriteLn ;


(*
   Read - reads a single character.
*)

PROCEDURE Read (VAR ch: CHAR) ;


(*
   KeyPressed - returns TRUE if a character can be read without blocking
                the caller.
*)

PROCEDURE KeyPressed () : BOOLEAN ;


(*
   ReadString - reads a sequence of characters.
                Tabs are expanded into 8 spaces and <cr> or <lf> terminates
                the string.
*)

PROCEDURE ReadString (VAR s: ARRAY OF CHAR) ;


(*
   ReadAgain - makes the last character readable again.
*)

PROCEDURE ReadAgain ;


(*
   Write - writes a single character to the Termbase module.
*)
```

```
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 - switchs 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 is 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 M2 ISO Libraries

This directory contains the ISO definition modules and some corresponding implementation modules. The definition files: `ChanConsts.def`, `CharClass.def`, `ComplexMath.def`, `ConvStringLong.def`, `ConvStringReal.def`, `ConvTypes.def`, `COROUTINES.def`, `EXCEPTIONS.def`, `GeneralUserExceptions.def`, `IOChan.def`, `IOConsts.def`, `IOLink.def`, `IOLink.def`, `IOResult.def`, `LongComplexMath.def`, `LongConv.def`, `LongIO.def`, `LongMath.def`, `LongStr.def`, `LowLong.def`, `LowReal.def`, `M2EXCEPTION.def`, `Processes.def`, `ProgramArgs.def`, `RawIO.def`, `RealConv.def`, `RealIO.def`, `RealMath.def`, `RealStr.def`, `RndFile.def`, `Semaphores.def`, `SeqFile.def`, `SIOResult.def`, `SLongIO.def`, `SRawIO.def`, `SRealIO.def`, `StdChans.def`, `STextIO.def`, `Storage.def`, `StreamFile.def`, `Strings.def`, `SWholeIO.def`, `SysClock.def`, `SYSTEM.def`, `TERMINATION.def`, `TextIO.def`, `WholeConv.def`, `WholeIO.def` and `WholeStr.def` were defined by the International Standard Information technology - programming languages BS ISO/IEC 10514-1:1996E Part 1: Modula-2, Base Language.

The Copyright to the definition files `ChanConsts.def`, `CharClass.def`, `ComplexMath.def`, `ConvStringLong.def`, `ConvStringReal.def`, `ConvTypes.def`, `COROUTINES.def`, `EXCEPTIONS.def`, `GeneralUserExceptions.def`, `IOChan.def`, `IOConsts.def`, `IOLink.def`, `IOLink.def`, `IOResult.def`, `LongComplexMath.def`, `LongConv.def`, `LongIO.def`, `LongMath.def`, `LongStr.def`, `LowLong.def`, `LowReal.def`, `M2EXCEPTION.def`, `Processes.def`, `ProgramArgs.def`, `RawIO.def`, `RealConv.def`, `RealIO.def`, `RealMath.def`, `RealStr.def`, `RndFile.def`, `Semaphores.def`, `SeqFile.def`, `SIOResult.def`, `SLongIO.def`, `SRawIO.def`, `SRealIO.def`, `StdChans.def`, `STextIO.def`, `Storage.def`, `StreamFile.def`, `Strings.def`, `SWholeIO.def`, `SysClock.def`, `SYSTEM.def`, `TERMINATION.def`, `TextIO.def`, `WholeConv.def`, `WholeIO.def` and `WholeStr.def` belong to ISO/IEC (International Organization for Standardization and International Electrotechnical Commission). The licence allows them to be distributed with the compiler (as described on page 707 of the Information technology - Programming languages Part 1: Modula-2, Base Language. BS ISO/IEC 10514-1:1996).

All implementation modules and `ClientSocket.def`, `LongWholeIO.def`, `M2RTS.def`, `MemStream.def`, `pth.def`, `RandomNumber.def`, `RTdata.def`, `RTentity.def`, `RTfio.def`, `RTio.def`, `ShortComplexMath.def`, `ShortIO.def`, `ShortWholeIO.def`, `SimpleCipher.def`, `SLongWholeIO.def`, `SShortIO.def`, `SShortWholeIO.def`, `StringChan.def` and `wraptime.def` are Copyright of the FSF and are held under the GPLv3 with runtime exceptions.

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/`.

Notice that GNU Modula-2 contains additional libraries for input/output of `SHORTREAL`, `SHORTCARD`, `SHORTINT`, `LONGCARD`, `LONGINT` data types. It also provides a `RandomNumber`, `SimpleCipher` and `ClientSocket` modules as well as low level modules which allow the IO libraries to coexist with their PIM counterparts.

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.
  *)
```

```
PROCEDURE ATTACH (source: INTERRUPTSOURCE);
  (* Associates the specified source of interrupts with the calling
     coroutine. *)

PROCEDURE DETACH (source: INTERRUPTSOURCE);
  (* Dissociates the specified source of interrupts from the calling
     coroutine. *)

PROCEDURE IsATTACHED (source: INTERRUPTSOURCE): BOOLEAN;
  (* Returns TRUE if and only if the specified source of interrupts is
     currently associated with a coroutine; otherwise returns FALSE.
  *)

PROCEDURE HANDLER (source: INTERRUPTSOURCE): COROUTINE;
  (* Returns the coroutine, if any, that is associated with the source
     of interrupts. The result is undefined if IsATTACHED(source) =
     FALSE.
  *)

PROCEDURE CURRENT (): COROUTINE;
  (* Returns the identity of the calling coroutine. *)

PROCEDURE LISTEN (p: PROTECTION);
  (* Momentarily changes the protection of the calling coroutine to
     p. *)

PROCEDURE PROT (): PROTECTION;
  (* Returns the protection of the calling coroutine. *)


(*
   TurnInterrupts - switches processor interrupts to the protection
                    level, to.  It returns the old value.
*)

PROCEDURE TurnInterrupts (to: PROTECTION) : PROTECTION ;


(*
   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.
```

```
                 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.
```

4.4.2 gm2-libs-iso/ChanConsts

```
DEFINITION MODULE ChanConsts;

  (* Common types and values for channel open requests and results *)

TYPE
  ChanFlags =        (* Request flags possibly given when a channel is opened *)
  ( readFlag,        (* input operations are requested/available *)
    writeFlag,       (* output operations are requested/available *)
    oldFlag,         (* a file may/must/did exist before the channel is opened *)
    textFlag,        (* text operations are requested/available *)
    rawFlag,         (* raw operations are requested/available *)
    interactiveFlag, (* interactive use is requested/applies *)
    echoFlag         (* echoing by interactive device on removal of characters from input
                        stream requested/applies *)
  );

  FlagSet = SET OF ChanFlags;

  (* Singleton values of FlagSet, to allow for example, read + write *)

CONST
  read = FlagSet{readFlag};   (* input operations are requested/available *)
  write = FlagSet{writeFlag}; (* output operations are requested/available *)
  old = FlagSet{oldFlag};     (* a file may/must/did exist before the channel is opened *)
  text = FlagSet{textFlag};   (* text operations are requested/available *)
  raw = FlagSet{rawFlag};     (* raw operations are requested/available *)
  interactive = FlagSet{interactiveFlag}; (* interactive use is requested/applies *)
  echo = FlagSet{echoFlag};   (* echoing by interactive device on removal of characters from
                                 input stream requested/applies *)

TYPE
  OpenResults =        (* Possible results of open requests *)
    (opened,           (* the open succeeded as requested *)
     wrongNameFormat,  (* given name is in the wrong format for the implementation *)
     wrongFlags,       (* given flags include a value that does not apply to the device *)
     tooManyOpen,      (* this device cannot support any more open channels *)
     outOfChans,       (* no more channels can be allocated *)
     wrongPermissions, (* file or directory permissions do not allow request *)
     noRoomOnDevice,   (* storage limits on the device prevent the open *)
     noSuchFile,       (* a needed file does not exist *)
     fileExists,       (* a file of the given name already exists when a new one is required *)
     wrongFileType,    (* the file is of the wrong type to support the required operations *)
     noTextOperations, (* text operations have been requested, but are not supported *)
     noRawOperations,  (* raw operations have been requested, but are not supported *)
     noMixedOperations,(* text and raw operations have been requested, but they
```

```
                          are not supported in combination *)
    alreadyOpen,       (* the source/destination is already open for operations not supported
                          in combination with the requested operations *)
    otherProblem       (* open failed for some other reason *)
   );

END ChanConsts.
```

4.4.3 gm2-libs-iso/CharClass

```
DEFINITION MODULE CharClass;

  (* Classification of values of the type CHAR *)

PROCEDURE IsNumeric (ch: CHAR): BOOLEAN;
  (* Returns TRUE if and only if ch is classified as a numeric character *)

PROCEDURE IsLetter (ch: CHAR): BOOLEAN;
  (* Returns TRUE if and only if ch is classified as a letter *)

PROCEDURE IsUpper (ch: CHAR): BOOLEAN;
  (* Returns TRUE if and only if ch is classified as an upper case letter *)

PROCEDURE IsLower (ch: CHAR): BOOLEAN;
  (* Returns TRUE if and only if ch is classified as a lower case letter *)

PROCEDURE IsControl (ch: CHAR): BOOLEAN;
  (* Returns TRUE if and only if ch represents a control function *)

PROCEDURE IsWhiteSpace (ch: CHAR): BOOLEAN;
  (* Returns TRUE if and only if ch represents a space character or a format effector *)

END CharClass.
```

4.4.4 gm2-libs-iso/ClientSocket

```
DEFINITION MODULE ClientSocket ;

FROM IOChan IMPORT ChanId ;
FROM ChanConsts IMPORT FlagSet, OpenResults ;


(*
   OpenSocket - opens a TCP client connection to host:port.
*)

PROCEDURE OpenSocket (VAR cid: ChanId;
                      host: ARRAY OF CHAR; port: CARDINAL;
                      f: FlagSet; VAR res: OpenResults) ;

(*
   Close - if the channel identified by cid is not open to
           a socket 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) ;


(*
   IsSocket - tests if the channel identified by cid is open as
              a client socket stream.
*)

PROCEDURE IsSocket (cid: ChanId) : BOOLEAN ;


END ClientSocket.
```

4.4.5 gm2-libs-iso/ComplexMath

```
DEFINITION MODULE ComplexMath;

  (* Mathematical functions for the type COMPLEX *)

CONST
  i =    CMPLX (0.0, 1.0);
  one =  CMPLX (1.0, 0.0);
  zero = CMPLX (0.0, 0.0);

PROCEDURE __BUILTIN__ abs (z: COMPLEX): REAL;
  (* Returns the length of z *)

PROCEDURE __BUILTIN__ arg (z: COMPLEX): REAL;
  (* Returns the angle that z subtends to the positive real axis *)

PROCEDURE __BUILTIN__ conj (z: COMPLEX): COMPLEX;
  (* Returns the complex conjugate of z *)

PROCEDURE __BUILTIN__ power (base: COMPLEX; exponent: REAL): COMPLEX;
  (* Returns the value of the number base raised to the power exponent *)

PROCEDURE __BUILTIN__ sqrt (z: COMPLEX): COMPLEX;
  (* Returns the principal square root of z *)

PROCEDURE __BUILTIN__ exp (z: COMPLEX): COMPLEX;
  (* Returns the complex exponential of z *)

PROCEDURE __BUILTIN__ ln (z: COMPLEX): COMPLEX;
  (* Returns the principal value of the natural logarithm of z *)

PROCEDURE __BUILTIN__ sin (z: COMPLEX): COMPLEX;
  (* Returns the sine of z *)

PROCEDURE __BUILTIN__ cos (z: COMPLEX): COMPLEX;
  (* Returns the cosine of z *)

PROCEDURE __BUILTIN__ tan (z: COMPLEX): COMPLEX;
  (* Returns the tangent of z *)

PROCEDURE __BUILTIN__ arcsin (z: COMPLEX): COMPLEX;
  (* Returns the arcsine of z *)

PROCEDURE __BUILTIN__ arccos (z: COMPLEX): COMPLEX;
  (* Returns the arccosine of z *)
```

```
PROCEDURE __BUILTIN__ arctan (z: COMPLEX): COMPLEX;
  (* Returns the arctangent of z *)

PROCEDURE polarToComplex (abs, arg: REAL): COMPLEX;
  (* Returns the complex number with the specified polar coordinates *)

PROCEDURE scalarMult (scalar: REAL; z: COMPLEX): COMPLEX;
  (* 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 ComplexMath.
```

4.4.6 gm2-libs-iso/ConvStringLong

```
DEFINITION MODULE ConvStringLong ;

FROM DynamicStrings IMPORT String ;


(*
   RealToFloatString - converts a real with, sigFigs, into a string
                       and returns the result as a string.
*)

PROCEDURE RealToFloatString (real: LONGREAL; 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: LONGREAL; 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: LONGREAL; place: INTEGER) : String ;


END ConvStringLong.
```

4.4.7 gm2-libs-iso/ConvStringReal

```
DEFINITION MODULE ConvStringReal ;

FROM DynamicStrings IMPORT String ;


(*
   RealToFloatString - converts a real with, sigFigs, into a string
                       and returns the result as a string.
*)

PROCEDURE RealToFloatString (real: REAL; 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: REAL; 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: REAL; place: INTEGER) : String ;


END ConvStringReal.
```

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 scanners *)
  (
    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 ;
```

```
END ErrnoCategory.
```

4.4.12 gm2-libs-iso/GeneralUserExceptions

```
DEFINITION MODULE GeneralUserExceptions;

(* Provides facilities for general user-defined exceptions *)

TYPE
  GeneralExceptions = (problem, disaster);

PROCEDURE RaiseGeneralException (exception: GeneralExceptions;
                                 text: ARRAY OF CHAR);
  (* Raises exception using text as the associated message *)

PROCEDURE IsGeneralException (): BOOLEAN;
  (* Returns TRUE if the current coroutine is in the exceptional
     execution state because of the raising of an exception from
     GeneralExceptions; otherwise returns FALSE.
  *)

PROCEDURE GeneralException(): GeneralExceptions;
  (* If the current coroutine is in the exceptional execution
     state because of the raising of an exception from
     GeneralExceptions, returns the corresponding enumeration value,
     and otherwise raises an exception.
  *)

END GeneralUserExceptions.
```

4.4.13 gm2-libs-iso/IOChan

```
DEFINITION MODULE IOChan;

  (* Types and procedures forming the interface to channels for
     device-independent data transfer modules
  *)

IMPORT IOConsts, ChanConsts, SYSTEM;

TYPE
  ChanId; (* Values of this type are used to identify channels *)

  (* There is one pre-defined value identifying an invalid channel
     on which no data transfer operations are available.  It may
     be used to initialize variables of type ChanId.
  *)

PROCEDURE InvalidChan (): ChanId;
  (* Returns the value identifying the invalid channel. *)

  (* For each of the following operations, if the device supports
     the operation on the channel, the behaviour of the procedure
     conforms with the description below.  The full behaviour is
     defined for each device module.  If the device does not
     support the operation on the channel, the behaviour of the
     procedure is to raise the exception notAvailable.
  *)

  (* Text operations - these perform any required translation between the
     internal and external representation of text.
  *)

PROCEDURE Look (cid: ChanId; VAR ch: CHAR; VAR res: IOConsts.ReadResults);
  (* If there is a character as the next item in the input stream
     cid, assigns its value to ch without removing it from the stream;
     otherwise the value of ch is not defined.  res (and the stored
     read result) are set to the value allRight, endOfLine, or endOfInput.
  *)

PROCEDURE Skip (cid: ChanId);
  (* If the input stream cid has ended, the exception skipAtEnd
     is raised; otherwise the next character or line mark in cid is
     removed, and the stored read result is set to the value
     allRight.
  *)
```

```
PROCEDURE SkipLook (cid: ChanId; VAR ch: CHAR; VAR res: IOConsts.ReadResults);
  (* If the input stream cid has ended, the exception skipAtEnd is
     raised; otherwise the next character or line mark in cid is
     removed.  If there is a character as the next item in cid
     stream, assigns its value to ch without removing it from the
     stream.  Otherwise, the value of ch is not defined.  res
     (and the stored read result) are set to the value allRight,
     endOfLine, or endOfInput.
  *)

PROCEDURE WriteLn (cid: ChanId);
  (* Writes a line mark over the channel cid. *)

PROCEDURE TextRead (cid: ChanId; to: SYSTEM.ADDRESS; maxChars: CARDINAL;
                    VAR charsRead: CARDINAL);
  (* Reads at most maxChars characters from the current line in cid,
     and assigns corresponding values to successive components of
     an ARRAY OF CHAR variable for which the address of the first
     component is to. The number of characters read is assigned to charsRead.
     The stored read result is set to allRight, endOfLine, or endOfInput.
  *)

PROCEDURE TextWrite (cid: ChanId; from: SYSTEM.ADDRESS;
                     charsToWrite: CARDINAL);
  (* Writes a number of characters given by the value of charsToWrite,
     from successive components of an ARRAY OF CHAR variable for which
     the address of the first component is from, to the channel cid.
  *)

  (* Direct raw operations  - these do not effect translation between
     the internal and external representation of data
  *)

PROCEDURE RawRead (cid: ChanId; to: SYSTEM.ADDRESS; maxLocs: CARDINAL;
                   VAR locsRead: CARDINAL);
  (* Reads at most maxLocs items from cid, and assigns corresponding
     values to successive components of an ARRAY OF LOC variable for
     which the address of the first component is to. The number of
     characters read is assigned to charsRead. The stored read result
     is set to the value allRight, or endOfInput.
  *)

PROCEDURE RawWrite (cid: ChanId; from: SYSTEM.ADDRESS; locsToWrite: CARDINAL);
  (* Writes a number of items given by the value of charsToWrite,
     from successive components of an ARRAY OF LOC variable for
     which the address of the first component is from, to the channel cid.
  *)
```

```
  (* Common operations *)

PROCEDURE GetName (cid: ChanId; VAR s: ARRAY OF CHAR);
  (* Copies to s a name associated with the channel cid, possibly truncated
     (depending on the capacity of s).
  *)

PROCEDURE Reset (cid: ChanId);
  (* Resets the channel cid to a state defined by the device module. *)

PROCEDURE Flush (cid: ChanId);
  (* Flushes any data buffered by the device module out to the channel cid. *)

  (* Access to read results *)

PROCEDURE SetReadResult (cid: ChanId; res: IOConsts.ReadResults);
  (* Sets the read result value for the channel cid to the value res. *)

PROCEDURE ReadResult (cid: ChanId): IOConsts.ReadResults;
  (* Returns the stored read result value for the channel cid.
     (This is initially the value notKnown).
  *)

  (* Users can discover which flags actually apply to a channel *)

PROCEDURE CurrentFlags (cid: ChanId): ChanConsts.FlagSet;
  (* Returns the set of flags that currently apply to the channel cid. *)

  (* The following exceptions are defined for this module and its clients *)

TYPE
  ChanExceptions =
    (wrongDevice,      (* device specific operation on wrong device *)
     notAvailable,     (* operation attempted that is not available on that
                          channel *)
     skipAtEnd,        (* attempt to skip data from a stream that has ended *)
     softDeviceError,  (* device specific recoverable error *)
     hardDeviceError,  (* device specific non-recoverable error *)
     textParseError,   (* input data does not correspond to a character or
                          line mark - optional detection *)
     notAChannel       (* given value does not identify a channel -
                          optional detection *)
    );

PROCEDURE IsChanException (): BOOLEAN;
  (* Returns TRUE if the current coroutine is in the exceptional
```

```
     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.
```

4.4.15 gm2-libs-iso/IOLink

```
DEFINITION MODULE IOLink;

(* Types and procedures for the standard implementation of channels *)

IMPORT IOChan, IOConsts, ChanConsts, SYSTEM;

TYPE
  DeviceId;
    (* Values of this type are used to identify new device modules,
       and are normally obtained by them during their initialization.
    *)

PROCEDURE AllocateDeviceId (VAR did: DeviceId);
  (* Allocates a unique value of type DeviceId, and assigns this
     value to did. *)

PROCEDURE MakeChan (did: DeviceId; VAR cid: IOChan.ChanId);
  (* Attempts to make a new channel for the device module identified
     by did. If no more channels can be made, the identity of
     the invalid channel is assigned to cid.  Otherwise, the identity
     of a new channel is assigned to cid.
  *)

PROCEDURE UnMakeChan (did: DeviceId; VAR cid: IOChan.ChanId);
  (* 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 channel is deallocated, and the value
     identifying the invalid channel is assigned to cid.
  *)

TYPE
  DeviceTablePtr = POINTER TO DeviceTable;
    (* Values of this type are used to refer to device tables *)

TYPE
  LookProc      = PROCEDURE (DeviceTablePtr, VAR CHAR, VAR IOConsts.ReadResults) ;
  SkipProc      = PROCEDURE (DeviceTablePtr) ;
  SkipLookProc  = PROCEDURE (DeviceTablePtr, VAR CHAR, VAR IOConsts.ReadResults) ;
  WriteLnProc   = PROCEDURE (DeviceTablePtr) ;
  TextReadProc  = PROCEDURE (DeviceTablePtr, SYSTEM.ADDRESS, CARDINAL, VAR CARDINAL) ;
  TextWriteProc = PROCEDURE (DeviceTablePtr, SYSTEM.ADDRESS, CARDINAL) ;
  RawReadProc   = PROCEDURE (DeviceTablePtr, SYSTEM.ADDRESS, CARDINAL, VAR CARDINAL) ;
  RawWriteProc  = PROCEDURE (DeviceTablePtr, SYSTEM.ADDRESS, CARDINAL) ;
  GetNameProc   = PROCEDURE (DeviceTablePtr, VAR ARRAY OF CHAR) ;
  ResetProc     = PROCEDURE (DeviceTablePtr) ;
```

```
  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 exception
     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.
```

4.4.19 gm2-libs-iso/LongIO

```
DEFINITION MODULE LongIO;

  (* Input and output of long real 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 fixed-point real number is
       ["+" | "-"], decimal digit, {decimal digit}, [".",
       {decimal digit}]

     The text form of a signed floating-point real number is
       signed fixed-point real number,
       "E", ["+" | "-"], decimal digit, {decimal digit}
  *)

PROCEDURE ReadReal (cid: IOChan.ChanId; VAR real: LONGREAL);
  (* Skips leading spaces, and removes any remaining characters
     from cid that form part of a signed fixed or floating
     point number.  The value of this number is assigned to real.
     The read result is set to the value allRight, outOfRange,
     wrongFormat, endOfLine, or endOfInput.
  *)

PROCEDURE WriteFloat (cid: IOChan.ChanId; real: LONGREAL;
                      sigFigs: CARDINAL; width: CARDINAL);
  (* Writes the value of real to cid in floating-point text form,
     with sigFigs significant figures, in a field of the given
     minimum width.
  *)

PROCEDURE WriteEng (cid: IOChan.ChanId; real: LONGREAL;
                    sigFigs: CARDINAL; width: CARDINAL);
  (* As for WriteFloat, except that 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 WriteFixed (cid: IOChan.ChanId; real: LONGREAL;
                      place: INTEGER; width: CARDINAL);
  (* Writes the value of real to cid in fixed-point text form,
     rounded to the given place relative to the decimal point,
     in a field of the given minimum width.
```

```
  *)

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.
```

4.4.20 gm2-libs-iso/LongMath

```
DEFINITION MODULE LongMath;

  (* Mathematical functions for the type LONGREAL *)

CONST
  pi   = 3.1415926535897932384626433832795028841972;
  exp1 = 2.7182818284590452353602874713526624977572;

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

PROCEDURE __BUILTIN__ exp (x: LONGREAL): LONGREAL;
  (* Returns the exponential of x *)

PROCEDURE __BUILTIN__ ln (x: LONGREAL): LONGREAL;
  (* Returns the natural logarithm of x *)

  (* The angle in all trigonometric functions is measured in radians *)

PROCEDURE __BUILTIN__ sin (x: LONGREAL): LONGREAL;
  (* Returns the sine of x *)

PROCEDURE __BUILTIN__ cos (x: LONGREAL): LONGREAL;
  (* Returns the cosine of x *)

PROCEDURE tan (x: LONGREAL): LONGREAL;
  (* Returns the tangent of x *)

PROCEDURE arcsin (x: LONGREAL): LONGREAL;
  (* Returns the arcsine of x *)

PROCEDURE arccos (x: LONGREAL): LONGREAL;
  (* Returns the arccosine of x *)

PROCEDURE arctan (x: LONGREAL): LONGREAL;
  (* Returns the arctangent of x *)

PROCEDURE power (base, exponent: LONGREAL): LONGREAL;
  (* Returns the value of the number base raised to the power exponent *)

PROCEDURE round (x: LONGREAL): 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 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.
```

4.4.23 gm2-libs-iso/LowLong

```
DEFINITION MODULE LowLong;

  (* Access to underlying properties of the type LONGREAL *)

CONST
  radix      = __ATTRIBUTE__ __BUILTIN__ (( <LONGREAL, radix> )) ;      (* ZType *)
  places     = __ATTRIBUTE__ __BUILTIN__ (( <LONGREAL, places> )) ;     (* ZType *)
  expoMin    = __ATTRIBUTE__ __BUILTIN__ (( <LONGREAL, expoMin> )) ;    (* ZType *)
  expoMax    = __ATTRIBUTE__ __BUILTIN__ (( <LONGREAL, expoMax> )) ;    (* ZType *)
  large      = __ATTRIBUTE__ __BUILTIN__ (( <LONGREAL, large> )) ;      (* RType *)
  small      = __ATTRIBUTE__ __BUILTIN__ (( <LONGREAL, small> )) ;      (* RType *)
  IEC559     = __ATTRIBUTE__ __BUILTIN__ (( <LONGREAL, IEC559> )) ;     (* BOOLEAN *)
  LIA1       = __ATTRIBUTE__ __BUILTIN__ (( <LONGREAL, LIA1> )) ;       (* BOOLEAN *)
  ISO        = __ATTRIBUTE__ __BUILTIN__ (( <LONGREAL, ISO> )) ;        (* BOOLEAN *)
  IEEE       = __ATTRIBUTE__ __BUILTIN__ (( <LONGREAL, IEEE> )) ;       (* BOOLEAN *)
  rounds     = __ATTRIBUTE__ __BUILTIN__ (( <LONGREAL, rounds> )) ;     (* BOOLEAN *)
  gUnderflow = __ATTRIBUTE__ __BUILTIN__ (( <LONGREAL, gUnderflow> )) ; (* BOOLEAN *)
  exception  = __ATTRIBUTE__ __BUILTIN__ (( <LONGREAL, exception> )) ;  (* BOOLEAN *)
  extend     = __ATTRIBUTE__ __BUILTIN__ (( <LONGREAL, extend> )) ;     (* BOOLEAN *)
  nModes     = __ATTRIBUTE__ __BUILTIN__ (( <LONGREAL, nModes> )) ;     (* ZType *)

TYPE
  Modes = PACKEDSET OF [0 .. nModes-1];

PROCEDURE exponent (x: LONGREAL): INTEGER;
  (* Returns the exponent value of x *)

PROCEDURE fraction (x: LONGREAL): LONGREAL;
  (* Returns the significand (or significant part) of x *)

PROCEDURE sign (x: LONGREAL): LONGREAL;
  (* Returns the signum of x *)

PROCEDURE succ (x: LONGREAL): LONGREAL;
  (* Returns the next value of the type LONGREAL greater than x *)

PROCEDURE ulp (x: LONGREAL): LONGREAL;
  (* Returns the value of a unit in the last place of x *)

PROCEDURE pred (x: LONGREAL): LONGREAL;
  (* Returns the previous value of the type LONGREAL less than x *)

PROCEDURE intpart (x: LONGREAL): LONGREAL;
  (* Returns the integer part of x *)
```

```
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.
```

4.4.24 gm2-libs-iso/LowReal

```
DEFINITION MODULE LowReal;

  (* Access to underlying properties of the type REAL *)

CONST
  radix      = __ATTRIBUTE__ __BUILTIN__ (( <REAL, radix> )) ;      (* ZType *)
  places     = __ATTRIBUTE__ __BUILTIN__ (( <REAL, places> )) ;     (* ZType *)
  expoMin    = __ATTRIBUTE__ __BUILTIN__ (( <REAL, expoMin> )) ;    (* ZType *)
  expoMax    = __ATTRIBUTE__ __BUILTIN__ (( <REAL, expoMax> )) ;    (* ZType *)
  large      = __ATTRIBUTE__ __BUILTIN__ (( <REAL, large> )) ;      (* RType *)
  small      = __ATTRIBUTE__ __BUILTIN__ (( <REAL, small> )) ;      (* RType *)
  IEC559     = __ATTRIBUTE__ __BUILTIN__ (( <REAL, IEC559> )) ;     (* BOOLEAN *)
  LIA1       = __ATTRIBUTE__ __BUILTIN__ (( <REAL, LIA1> )) ;       (* BOOLEAN *)
  ISO        = __ATTRIBUTE__ __BUILTIN__ (( <REAL, ISO> )) ;        (* BOOLEAN *)
  IEEE       = __ATTRIBUTE__ __BUILTIN__ (( <REAL, IEEE> )) ;       (* BOOLEAN *)
  rounds     = __ATTRIBUTE__ __BUILTIN__ (( <REAL, rounds> )) ;     (* BOOLEAN *)
  gUnderflow = __ATTRIBUTE__ __BUILTIN__ (( <REAL, gUnderflow> )) ; (* BOOLEAN *)
  exception  = __ATTRIBUTE__ __BUILTIN__ (( <REAL, exception> )) ;  (* BOOLEAN *)
  extend     = __ATTRIBUTE__ __BUILTIN__ (( <REAL, extend> )) ;     (* BOOLEAN *)
  nModes     = __ATTRIBUTE__ __BUILTIN__ (( <REAL, nModes> )) ;     (* ZType *)

TYPE
  Modes = PACKEDSET OF [0..nModes-1];

PROCEDURE exponent (x: REAL): INTEGER;
  (* Returns the exponent value of x *)

PROCEDURE fraction (x: REAL): REAL;
  (* Returns the significand (or significant part) of x *)

PROCEDURE sign (x: REAL): REAL;
  (* Returns the signum of x *)

PROCEDURE succ (x: REAL): REAL;
  (* Returns the next value of the type REAL greater than x *)

PROCEDURE ulp (x: REAL): REAL;
  (* Returns the value of a unit in the last place of x *)

PROCEDURE pred (x: REAL): REAL;
  (* Returns the previous value of the type REAL less than x *)

PROCEDURE intpart (x: REAL): REAL;
  (* Returns the integer part of x *)
```

```
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.
```

4.4.25 gm2-libs-iso/LowShort

```
DEFINITION MODULE LowShort;

  (* Access to underlying properties of the type SHORTREAL *)

CONST
  radix      = __ATTRIBUTE__ __BUILTIN__ (( <SHORTREAL, radix> )) ;      (* ZType *)
  places     = __ATTRIBUTE__ __BUILTIN__ (( <SHORTREAL, places> )) ;     (* ZType *)
  expoMin    = __ATTRIBUTE__ __BUILTIN__ (( <SHORTREAL, expoMin> )) ;    (* ZType *)
  expoMax    = __ATTRIBUTE__ __BUILTIN__ (( <SHORTREAL, expoMax> )) ;    (* ZType *)
  large      = __ATTRIBUTE__ __BUILTIN__ (( <SHORTREAL, large> )) ;      (* RType *)
  small      = __ATTRIBUTE__ __BUILTIN__ (( <SHORTREAL, small> )) ;      (* RType *)
  IEC559     = __ATTRIBUTE__ __BUILTIN__ (( <SHORTREAL, IEC559> )) ;     (* BOOLEAN *)
  LIA1       = __ATTRIBUTE__ __BUILTIN__ (( <SHORTREAL, LIA1> )) ;       (* BOOLEAN *)
  ISO        = __ATTRIBUTE__ __BUILTIN__ (( <SHORTREAL, ISO> )) ;        (* BOOLEAN *)
  IEEE       = __ATTRIBUTE__ __BUILTIN__ (( <SHORTREAL, IEEE> )) ;       (* BOOLEAN *)
  rounds     = __ATTRIBUTE__ __BUILTIN__ (( <SHORTREAL, rounds> )) ;     (* BOOLEAN *)
  gUnderflow = __ATTRIBUTE__ __BUILTIN__ (( <SHORTREAL, gUnderflow> )) ; (* BOOLEAN *)
  exception  = __ATTRIBUTE__ __BUILTIN__ (( <SHORTREAL, exception> )) ;  (* BOOLEAN *)
  extend     = __ATTRIBUTE__ __BUILTIN__ (( <SHORTREAL, extend> )) ;     (* BOOLEAN *)
  nModes     = __ATTRIBUTE__ __BUILTIN__ (( <SHORTREAL, nModes> )) ;     (* ZType *)

TYPE
  Modes = PACKEDSET OF [0 .. nModes-1];

PROCEDURE exponent (x: SHORTREAL): INTEGER;
  (* Returns the exponent value of x *)

PROCEDURE fraction (x: SHORTREAL): SHORTREAL;
  (* Returns the significand (or significant part) of x *)

PROCEDURE sign (x: SHORTREAL): SHORTREAL;
  (* Returns the signum of x *)

PROCEDURE succ (x: SHORTREAL): SHORTREAL;
  (* Returns the next value of the type SHORTREAL greater than x *)

PROCEDURE ulp (x: SHORTREAL): SHORTREAL;
  (* Returns the value of a unit in the last place of x *)

PROCEDURE pred (x: SHORTREAL): SHORTREAL;
  (* Returns the previous value of the type SHORTREAL less than x *)

PROCEDURE intpart (x: SHORTREAL): SHORTREAL;
  (* Returns the integer part of x *)
```

```
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,    realValueException,
     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
   ArgCVEnvP = PROCEDURE (INTEGER, ADDRESS, ADDRESS) ;


PROCEDURE ConstructModules (applicationmodule, libname: ADDRESS;
                            overrideliborder: 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:  ArgCVEnvP;
                          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 is 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 ;
```

```
(*
   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) <* noreturn *> ;
PROCEDURE ReturnException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE IncException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE DecException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE InclException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE ExclException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE ShiftException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE RotateException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE StaticArraySubscriptException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE DynamicArraySubscriptException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE ForLoopBeginException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE ForLoopToException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE ForLoopEndException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE PointerNilException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE NoReturnException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE CaseException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE WholeNonPosDivException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE WholeNonPosModException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE WholeZeroDivException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE WholeZeroRemException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE WholeValueException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE RealValueException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE ParameterException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;
PROCEDURE NoException (filename: ADDRESS; line, column: CARDINAL; scope, message: ADDRESS) <* noreturn *> ;


END M2RTS.
```

4.4.28 gm2-libs-iso/MemStream

```
DEFINITION MODULE MemStream ;

(*
    Description: provides an ISO module which can write to a memory
                 buffer or read from a memory buffer.
*)

FROM IOChan IMPORT ChanId ;
FROM ChanConsts IMPORT FlagSet, OpenResults ;
FROM SYSTEM IMPORT ADDRESS, LOC ;


(*
   Attempts to obtain and open a channel connected to a contigeous
   buffer in memory.  The write flag is 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.
   If a channel cannot be opened as required,
   the value of res indicates the reason, and cid identifies the
   invalid channel.

   The parameters, buffer, length and used maybe updated as
   data is written.  The buffer maybe reallocated
   and its address might alter, however the parameters will
   always reflect the current active buffer.  When this
   channel is closed the buffer is deallocated and
   buffer will be set to NIL, length and used will be set to
   zero.
*)

PROCEDURE OpenWrite (VAR cid: ChanId; flags: FlagSet;
                     VAR res: OpenResults;
                     VAR buffer: ADDRESS;
                     VAR length: CARDINAL;
                     VAR used: CARDINAL;
                     deallocOnClose: BOOLEAN) ;


(*
   Attempts to obtain and open a channel connected to a contigeous
   buffer in memory.  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 buffer.  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; 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.
```

4.4.32 gm2-libs-iso/RTco

```
DEFINITION MODULE FOR "C" RTco ;

FROM SYSTEM IMPORT ADDRESS ;

IMPORT RTentity ;  (* Imported so the initialization call graph
                      understands that RTco.cc depends upon RTentity.  *)

(* init initializes the module and allows the application to lazily invoke threads.  *)

PROCEDURE init () : INTEGER ;

PROCEDURE initThread (p: PROC; stackSize: CARDINAL; interruptLevel: CARDINAL) : INTEGER ;

PROCEDURE initSemaphore (value: CARDINAL) : INTEGER ;

PROCEDURE wait (semaphore: INTEGER) ;

PROCEDURE signal (semaphore: INTEGER) ;

PROCEDURE transfer (VAR p1: INTEGER; p2: INTEGER) ;

PROCEDURE waitThread (tid: INTEGER) ;

PROCEDURE signalThread (tid: INTEGER) ;

PROCEDURE currentThread () : INTEGER ;


(* currentInterruptLevel returns the interrupt level of the current thread.  *)

PROCEDURE currentInterruptLevel () : CARDINAL ;


(* turninterrupts returns the old interrupt level and assigns the interrupt level
   to newLevel.  *)

PROCEDURE turnInterrupts (newLevel: CARDINAL) : CARDINAL ;


(*
   select access to the select system call which will be thread safe.
   This is typically called from the idle process to wait for an interrupt.
*)

PROCEDURE select (p1: INTEGER;
```

```
                    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 assocated 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.
```

4.4.34 gm2-libs-iso/RTentity

```
DEFINITION MODULE RTentity ;

(*
    Description: provides a set of routines for maintaining an
                 efficient mechanism to group opaque (or pointer)
                 data structures together.  Internally the
                 entities are grouped together using a binary
                 tree.  It does not use Storage - and instead
                 uses malloc, free from libc as Storage uses the
                 module to detect erroneous deallocations.
*)

IMPORT SYSTEM ;

TYPE
   Group ;


PROCEDURE InitGroup () : Group ;
PROCEDURE KillGroup (g: Group) : Group ;
PROCEDURE GetKey (g: Group; a: SYSTEM.ADDRESS) : CARDINAL ;
PROCEDURE PutKey (g: Group; a: SYSTEM.ADDRESS; key: CARDINAL) ;
PROCEDURE DelKey (g: Group; a: SYSTEM.ADDRESS) ;
PROCEDURE IsIn (g: Group; a: SYSTEM.ADDRESS) : BOOLEAN ;


END RTentity.
```

4.4.35 gm2-libs-iso/RTfio

```
DEFINITION MODULE RTfio ;

(*
    Description: provides default FIO based methods for the RTgenif
                 procedures.  These will be used by StreamFile,
                 SeqFile, StdChans, TermFile and RndFile.
*)

FROM SYSTEM IMPORT ADDRESS ;
FROM IOLink IMPORT DeviceTablePtr;
FROM RTgenif IMPORT GenDevIF ;


(*
   doreadchar - returns a CHAR from the file associated with, g.
*)

PROCEDURE doreadchar (g: GenDevIF; d: DeviceTablePtr) : CHAR ;


(*
   dounreadchar - pushes a CHAR back onto the file associated
                  with, g.
*)

PROCEDURE dounreadchar (g: GenDevIF; d: DeviceTablePtr; ch: CHAR) : CHAR ;


(*
   dogeterrno - returns the errno relating to the generic device.
*)

PROCEDURE dogeterrno (g: GenDevIF; d: DeviceTablePtr) : INTEGER ;


(*
   dorbytes - reads upto, max, bytes setting, actual, and
              returning FALSE if an error (not due to eof)
              occurred.
*)

PROCEDURE dorbytes (g: GenDevIF;
                    d: DeviceTablePtr;
                    to: ADDRESS;
                    max: CARDINAL;
```

```
                    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.
```

4.4.36 gm2-libs-iso/RTgen

```
DEFINITION MODULE RTgen ;

(*
    Description: provides a generic device interface between
                 ISO channels and the underlying PIM style
                 FIO procedure calls.
*)

FROM RTgenif IMPORT GenDevIF ;
FROM IOLink IMPORT DeviceId, DeviceTablePtr;
FROM IOConsts IMPORT ReadResults ;
FROM SYSTEM IMPORT ADDRESS ;


TYPE
   ChanDev ;
   DeviceType = (seqfile, streamfile, programargs, stdchans, term, socket, rndfile) ;


(*
   InitChanDev - initialize and return a ChanDev.
*)

PROCEDURE InitChanDev (t: DeviceType; d: DeviceId; g: GenDevIF) : ChanDev ;


(*
   KillChanDev - deallocates, g.
*)

PROCEDURE KillChanDev (g: GenDevIF) : GenDevIF ;


(*
   RaiseEOFinLook - returns TRUE if the Look procedure
                    should raise an exception if it
                    sees end of file.
*)

PROCEDURE RaiseEOFinLook (g: ChanDev) : BOOLEAN ;


(*
   RaiseEOFinSkip - returns TRUE if the Skip procedure
                    should raise an exception if it
```

```
                    sees end of file.
*)

PROCEDURE RaiseEOFinSkip (g: ChanDev) : BOOLEAN ;


PROCEDURE doLook (g: ChanDev;
                  d: DeviceTablePtr;
                  VAR ch: CHAR;
                  VAR r: ReadResults) ;

PROCEDURE doSkip (g: ChanDev;
                  d: DeviceTablePtr) ;

PROCEDURE doSkipLook (g: ChanDev;
                      d: DeviceTablePtr;
                      VAR ch: CHAR;
                      VAR r: ReadResults) ;

PROCEDURE doWriteLn (g: ChanDev;
                     d: DeviceTablePtr) ;

PROCEDURE doReadText (g: ChanDev;
                      d: DeviceTablePtr;
                      to: ADDRESS;
                      maxChars: CARDINAL;
                      VAR charsRead: CARDINAL) ;

PROCEDURE doWriteText (g: ChanDev;
                       d: DeviceTablePtr;
                       from: ADDRESS;
                       charsToWrite: CARDINAL) ;

PROCEDURE doReadLocs (g: ChanDev;
                      d: DeviceTablePtr;
                      to: ADDRESS;
                      maxLocs: CARDINAL;
                      VAR locsRead: CARDINAL) ;

PROCEDURE doWriteLocs (g: ChanDev;
                       d: DeviceTablePtr;
                       from: ADDRESS;
                       locsToWrite: CARDINAL) ;

(*
   checkErrno - checks a number of errno conditions and raises
                appropriate ISO exceptions if they occur.
```

```
*)

PROCEDURE checkErrno (g: ChanDev; d: DeviceTablePtr) ;


END RTgen.
```

4.4.37 gm2-libs-iso/RTgenif

```
DEFINITION MODULE RTgenif ;

(*
    Description: provides a generic interface mechanism used
                 by RTgen.  This is not an ISO module but rather
                 a runtime support module.
*)

FROM SYSTEM IMPORT ADDRESS ;
FROM IOLink IMPORT DeviceId, DeviceTablePtr ;

TYPE
   GenDevIF ;
   readchar   = PROCEDURE (GenDevIF, DeviceTablePtr) : CHAR ;
   unreadchar = PROCEDURE (GenDevIF, DeviceTablePtr, CHAR) : CHAR ;
   geterrno   = PROCEDURE (GenDevIF, DeviceTablePtr) : INTEGER ;
   readbytes  = PROCEDURE (GenDevIF, DeviceTablePtr, ADDRESS, CARDINAL, VAR CARDINAL) : BOOLEAN ;
   writebytes = PROCEDURE (GenDevIF, DeviceTablePtr, ADDRESS, CARDINAL, VAR CARDINAL) : BOOLEAN ;
   writeln    = PROCEDURE (GenDevIF, DeviceTablePtr) : BOOLEAN ;
   iseof      = PROCEDURE (GenDevIF, DeviceTablePtr) : BOOLEAN ;
   iseoln     = PROCEDURE (GenDevIF, DeviceTablePtr) : BOOLEAN ;
   iserror    = PROCEDURE (GenDevIF, DeviceTablePtr) : BOOLEAN ;


(*
   InitGenDevIF - initializes a generic device.
*)

PROCEDURE InitGenDevIF (d     : DeviceId;
                        rc    : readchar;
                        urc   : unreadchar;
                        geterr: geterrno;
                        rbytes: readbytes;
                        wbytes: writebytes;
                        wl    : writeln;
                        eof   : iseof;
                        eoln  : iseoln;
                        iserr : iserror) : GenDevIF ;


(*
   getDID - returns the device id this generic interface.
*)

PROCEDURE getDID (g: GenDevIF) : DeviceId ;
```

```
(*
   doReadChar - returns the next character from the generic
                device.
*)

PROCEDURE doReadChar (g: GenDevIF; d: DeviceTablePtr) : CHAR ;


(*
   doUnReadChar - pushes back a character to the generic device.
*)

PROCEDURE doUnReadChar (g: GenDevIF; d: DeviceTablePtr; ch: CHAR) : CHAR ;


(*
   doGetErrno - returns the errno relating to the generic device.
*)

PROCEDURE doGetErrno (g: GenDevIF; d: DeviceTablePtr) : INTEGER ;


(*
   doRBytes - attempts to read, n, bytes from the generic device.
              It set the actual amount read and returns a boolean
              to determine whether an error occurred.
*)

PROCEDURE doRBytes (g: GenDevIF; d: DeviceTablePtr;
                    to: ADDRESS; max: CARDINAL;
                    VAR actual: CARDINAL) : BOOLEAN ;


(*
   doWBytes - attempts to write, n, bytes to the generic device.
              It sets the actual amount written and returns a
              boolean to determine whether an error occurred.
*)

PROCEDURE doWBytes (g: GenDevIF; d: DeviceTablePtr;
                    from: ADDRESS; max: CARDINAL;
                    VAR actual: CARDINAL) : BOOLEAN ;


(*
```

```
   doWrLn - writes an end of line marker and returns
            TRUE if successful.
*)

PROCEDURE doWrLn (g: GenDevIF; d: DeviceTablePtr) : BOOLEAN ;


(*
   isEOF - returns true if the end of file was reached.
*)

PROCEDURE isEOF (g: GenDevIF; d: DeviceTablePtr) : BOOLEAN ;


(*
   isEOLN - returns true if the end of line was reached.
*)

PROCEDURE isEOLN (g: GenDevIF; d: DeviceTablePtr) : BOOLEAN ;


(*
   isError - returns true if an error was seen in the device.
*)

PROCEDURE isError (g: GenDevIF; d: DeviceTablePtr) : BOOLEAN ;


(*
   KillGenDevIF - deallocates a generic device.
*)

PROCEDURE KillGenDevIF (g: GenDevIF) : GenDevIF ;


END RTgenif.
```

4.4.38 gm2-libs-iso/RTio

```
DEFINITION MODULE RTio ;

(*
    Description: provides low level routines for creating and destroying
                 ChanIds.  This is necessary to allow multiple modules
                 to create, ChanId values, where ChanId is an opaque
                 type.
*)

IMPORT FIO, IOLink ;

TYPE
   ChanId ;


(*
   InitChanId - return a new ChanId.
*)

PROCEDURE InitChanId () : ChanId ;


(*
   KillChanId - deallocate a ChanId.
*)

PROCEDURE KillChanId (c: ChanId) : ChanId ;


(*
   NilChanId - return a NIL pointer.
*)

PROCEDURE NilChanId () : ChanId ;


(*
   GetDeviceId - returns the device id, from, c.
*)

PROCEDURE GetDeviceId (c: ChanId) : IOLink.DeviceId ;


(*
   SetDeviceId - sets the device id in, c.
```

```
*)

PROCEDURE SetDeviceId (c: ChanId; d: IOLink.DeviceId) ;


(*
   GetDevicePtr - returns the device table ptr, from, c.
*)

PROCEDURE GetDevicePtr (c: ChanId) : IOLink.DeviceTablePtr ;


(*
   SetDevicePtr - sets the device table ptr in, c.
*)

PROCEDURE SetDevicePtr (c: ChanId; p: IOLink.DeviceTablePtr) ;


(*
   GetFile - returns the file field from, c.
*)

PROCEDURE GetFile (c: ChanId) : FIO.File ;


(*
   SetFile - sets the file field in, c.
*)

PROCEDURE SetFile (c: ChanId; f: FIO.File) ;


END RTio.
```

4.4.39 gm2-libs-iso/RandomNumber

```
DEFINITION MODULE RandomNumber ;

(*
    Description: provides primitives for obtaining random numbers on
                 pervasive data types.
*)

FROM SYSTEM IMPORT BYTE ;
EXPORT QUALIFIED Randomize, RandomInit, RandomBytes,
                 RandomCard, RandomShortCard, RandomLongCard,
                 RandomInt, RandomShortInt, RandomLongInt,
                 RandomReal, RandomLongReal, RandomShortReal ;


(*
   Randomize - initialize the random number generator with a seed
               based on the microseconds.
*)

PROCEDURE Randomize ;


(*
   RandomInit - initialize the random number generator with value, seed.
*)

PROCEDURE RandomInit (seed: CARDINAL) ;


(*
   RandomBytes - fills in an array with random values.
*)

PROCEDURE RandomBytes (VAR a: ARRAY OF BYTE) ;


(*
   RandomInt - return an INTEGER in the range [low .. high].
*)

PROCEDURE RandomInt (low, high: INTEGER) : INTEGER ;


(*
   RandomShortInt - return an SHORTINT in the range [low..high].
```

```
*)

PROCEDURE RandomShortInt (low, high: SHORTINT) : SHORTINT ;


(*
   RandomLongInt - return an LONGINT in the range [low..high].
*)

PROCEDURE RandomLongInt (low, high: LONGINT) : LONGINT ;


(*
   RandomShortCard - return a SHORTCARD in the range [low..high].
*)

PROCEDURE RandomShortCard (low, high: CARDINAL) : CARDINAL ;


(*
   RandomCard - return a CARDINAL in the range [low..high].
*)

PROCEDURE RandomCard (low, high: CARDINAL) : CARDINAL ;


(*
   RandomLongCard - return an LONGCARD in the range [low..high].
*)

PROCEDURE RandomLongCard (low, high: LONGCARD) : LONGCARD ;


(*
   RandomReal - return a REAL number in the range 0.0..1.0
*)

PROCEDURE RandomReal () : REAL ;


(*
   RandomShortReal - return a SHORTREAL number in the range 0.0..1.0
*)

PROCEDURE RandomShortReal () : SHORTREAL ;
```

```
(*
   RandomLongReal - return a LONGREAL number in the range 0.0..1.0
*)

PROCEDURE RandomLongReal () : LONGREAL ;


END RandomNumber.
```

4.4.40 gm2-libs-iso/RawIO

```
DEFINITION MODULE RawIO;

  (* Reading and writing data over specified channels using raw
     operations, that is, with no conversion or interpretation.
     The read result is of the type IOConsts.ReadResults.
  *)

IMPORT IOChan, SYSTEM;

PROCEDURE Read (cid: IOChan.ChanId; VAR to: ARRAY OF SYSTEM.LOC);
  (* Reads storage units from cid, and assigns them to
     successive components of to. The read result is set
     to the value allRight, wrongFormat, or endOfInput.
  *)

PROCEDURE Write (cid: IOChan.ChanId; from: ARRAY OF SYSTEM.LOC);
  (* Writes storage units to cid from successive components
     of from. *)

END RawIO.
```

4.4.41 gm2-libs-iso/RealConv

```
DEFINITION MODULE RealConv;

  (* Low-level REAL/string conversions *)

IMPORT
  ConvTypes;

TYPE
  (* strAllRight, strOutOfRange, strWrongFormat, strEmpty *)
  ConvResults = ConvTypes.ConvResults;

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 REAL. *)

PROCEDURE ValueReal (str: ARRAY OF CHAR): REAL;
  (* Returns the value corresponding to the real number string value
     str if str is well-formed; otherwise raises the RealConv
     exception.
  *)

PROCEDURE LengthFloatReal (real: REAL; sigFigs: CARDINAL): CARDINAL;
  (* Returns the number of characters in the floating-point string
     representation of real with sigFigs significant figures.
  *)

PROCEDURE LengthEngReal (real: REAL; sigFigs: CARDINAL): CARDINAL;
  (* Returns the number of characters in the floating-point engineering
     string representation of real with sigFigs significant figures.
  *)

PROCEDURE LengthFixedReal (real: REAL; 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 RealConv.
```

4.4.42 gm2-libs-iso/RealIO

```
DEFINITION MODULE RealIO;

  (* Input and output of real 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 fixed-point real number is
       ["+" | "-"], decimal digit, {decimal digit},
       [".", {decimal digit}]

     The text form of a signed floating-point real number is
       signed fixed-point real number,
       "E", ["+" | "-"], decimal digit, {decimal digit}
  *)

PROCEDURE ReadReal (cid: IOChan.ChanId; VAR real: REAL);
  (* Skips leading spaces, and removes any remaining characters
     from cid that form part of a signed fixed or floating
     point number.  The value of this number is assigned to real.
     The read result is set to the value allRight, outOfRange,
     wrongFormat, endOfLine, or endOfInput.
  *)

PROCEDURE WriteFloat (cid: IOChan.ChanId; real: REAL;
                      sigFigs: CARDINAL; width: CARDINAL);
  (* Writes the value of real to cid in floating-point text form,
     with sigFigs significant figures, in a field of the given
     minimum width.
  *)

PROCEDURE WriteEng (cid: IOChan.ChanId; real: REAL;
                    sigFigs: CARDINAL; width: CARDINAL);
  (* As for WriteFloat, except that 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 WriteFixed (cid: IOChan.ChanId; real: REAL;
                      place: INTEGER; width: CARDINAL);
  (* Writes the value of real to cid in fixed-point text form,
     rounded to the given place relative to the decimal point,
     in a field of the given minimum width.
```

```
  *)

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.
```

4.4.43 gm2-libs-iso/RealMath

```
DEFINITION MODULE RealMath;

  (* Mathematical functions for the type REAL *)

CONST
  pi   = 3.1415926535897932384626433832795028841972;
  exp1 = 2.7182818284590452353602874713526624977572;

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

PROCEDURE __BUILTIN__ exp (x: REAL): REAL;
  (* Returns the exponential of x *)

PROCEDURE __BUILTIN__ ln (x: REAL): REAL;
  (* Returns the natural logarithm of x *)

  (* The angle in all trigonometric functions is measured in radians *)

PROCEDURE __BUILTIN__ sin (x: REAL): REAL;
  (* Returns the sine of x *)

PROCEDURE __BUILTIN__ cos (x: REAL): REAL;
  (* Returns the cosine of x *)

PROCEDURE tan (x: REAL): REAL;
  (* Returns the tangent of x *)

PROCEDURE arcsin (x: REAL): REAL;
  (* Returns the arcsine of x *)

PROCEDURE arccos (x: REAL): REAL;
  (* Returns the arccosine of x *)

PROCEDURE arctan (x: REAL): REAL;
  (* Returns the arctangent of x *)

PROCEDURE power (base, exponent: REAL) : REAL;
  (* Returns the value of the number base raised to the power exponent *)

PROCEDURE round (x: REAL) : 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 RealMath.
```

4.4.44 gm2-libs-iso/RealStr

```
DEFINITION MODULE RealStr;

  (* REAL/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: REAL;
                     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: REAL; 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: REAL; 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: REAL; 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: REAL; 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 are
     implementation-defined.
  *)

END RealStr.
```

4.4.45 gm2-libs-iso/RndFile

```
DEFINITION MODULE RndFile;

  (* Random access files *)

IMPORT IOChan, ChanConsts, SYSTEM;

TYPE
   ChanId = IOChan.ChanId;
   FlagSet = ChanConsts.FlagSet;
   OpenResults = ChanConsts.OpenResults;

   (* Accepted singleton values of FlagSet *)

CONST
   (* input operations are requested/available *)
   read = FlagSet{ChanConsts.readFlag};
   (* output operations are requested/available *)
   write = FlagSet{ChanConsts.writeFlag};
   (* a file may/must/did exist before the channel is opened *)
   old = FlagSet{ChanConsts.oldFlag};
   (* text operations are requested/available *)
   text = FlagSet{ChanConsts.textFlag};
   (* raw operations are requested/available *)
   raw = FlagSet{ChanConsts.rawFlag};

PROCEDURE OpenOld (VAR cid: ChanId; name: ARRAY OF CHAR; flags: FlagSet;
                   VAR res: OpenResults);
  (* Attempts to obtain and open a channel connected to a stored random
     access file of the given name.
     The old flag is implied; without the write flag, read is implied;
     without the text flag, raw is implied.
     If successful, assigns to cid the identity of the opened channel,
     assigns the value opened to res, and sets the read/write position
     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 OpenClean (VAR cid: ChanId; name: ARRAY OF CHAR; flags: FlagSet;
                     VAR res: OpenResults);
  (* Attempts to obtain and open a channel connected to a stored random
     access file of the given name.
     The write flag is implied; without the text flag, raw is implied.
     If successful, assigns to cid the identity of the opened channel,
     assigns the value opened to res, and truncates the file to zero length.
```

```
     If a channel cannot be opened as required, the value of res indicates
     the reason, and cid identifies the invalid channel.
  *)

PROCEDURE IsRndFile (cid: ChanId): BOOLEAN;
  (* Tests if the channel identified by cid is open to a random access file. *)

PROCEDURE IsRndFileException (): BOOLEAN;
  (* Returns TRUE if the current coroutine is in the exceptional execution
     state because of the raising of a RndFile exception; otherwise returns
     FALSE.
  *)

CONST
   FilePosSize = SIZE(LONGINT) ;
   (* <implementation-defined whole number greater than zero>; *)

TYPE
   FilePos = LONGINT ;  (* ARRAY [1 .. FilePosSize] OF SYSTEM.LOC; *)

PROCEDURE StartPos (cid: ChanId): FilePos;
  (* If the channel identified by cid is not open to a random access file,
     the exception wrongDevice is raised; otherwise returns the position of
     the start of the file.
  *)

PROCEDURE CurrentPos (cid: ChanId): FilePos;
  (* If the channel identified by cid is not open to a random access file,
     the exception wrongDevice is raised; otherwise returns the position
     of the current read/write position.
  *)

PROCEDURE EndPos (cid: ChanId): FilePos;
  (* If the channel identified by cid is not open to a random access file,
     the exception wrongDevice is raised; otherwise returns the first
     position after which there have been no writes.
  *)

PROCEDURE NewPos (cid: ChanId; chunks: INTEGER; chunkSize: CARDINAL;
                  from: FilePos): FilePos;
  (* If the channel identified by cid is not open to a random access file,
     the exception wrongDevice is raised; otherwise returns the position
     (chunks * chunkSize) relative to the position given by from, or
     raises the exception posRange if the required position cannot be
     represented as a value of type FilePos.
  *)
```

```
PROCEDURE SetPos (cid: ChanId; pos: FilePos);
  (* If the channel identified by cid is not open to a random access file,
     the exception wrongDevice is raised; otherwise sets the read/write
     position to the value given by pos.
  *)

PROCEDURE Close (VAR cid: ChanId);
  (* If the channel identified by cid is not open to a random access file,
     the exception wrongDevice is raised; otherwise closes the channel,
     and assigns the value identifying the invalid channel to cid.
  *)

END RndFile.
```

4.4.46 gm2-libs-iso/SIOResult

```
DEFINITION MODULE SIOResult;

  (* Read results for the default input channel *)

IMPORT IOConsts;

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 (): ReadResults;
  (* Returns the result for the last read operation on the default input channel. *)

END SIOResult.
```

4.4.47 gm2-libs-iso/SLongIO

```
DEFINITION MODULE SLongIO;

  (* Input and output of long real numbers in decimal text form
     using default channels.  The read result is of the type
     IOConsts.ReadResults.
  *)

  (* The text form of a signed fixed-point real number is
       ["+" | "-"], decimal digit, {decimal digit},
       [".", {decimal digit}]

     The text form of a signed floating-point real number is
       signed fixed-point real number,
       "E", ["+" | "-"], decimal digit, {decimal digit}
  *)

PROCEDURE ReadReal (VAR real: LONGREAL);
  (* Skips leading spaces, and removes any remaining characters
     from the default input channel that form part of a signed
     fixed or floating point number. The value of this number
     is assigned to real.  The read result is set to the value
     allRight, outOfRange, wrongFormat, endOfLine, or endOfInput.
  *)

PROCEDURE WriteFloat (real: LONGREAL; sigFigs: CARDINAL;
                      width: CARDINAL);
  (* Writes the value of real to the default output channel in
     floating-point text form, with sigFigs significant figures,
     in a field of the given minimum width.
  *)

PROCEDURE WriteEng (real: LONGREAL; sigFigs: CARDINAL;
                    width: CARDINAL);
  (* As for WriteFloat, except that 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 WriteFixed (real: LONGREAL; place: INTEGER;
                      width: CARDINAL);
  (* Writes the value of real to the default output channel in
     fixed-point text form, rounded to the given place relative
     to the decimal point, in a field of the given minimum width.
  *)
```

```
PROCEDURE WriteReal (real: LONGREAL; width: CARDINAL);
  (* Writes the value of real to the default output channel, 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 SLongIO.
```

4.4.48 gm2-libs-iso/SLongWholeIO

```
DEFINITION MODULE SLongWholeIO;

  (* Input and output of whole numbers in decimal text form over
     default channels.  The read result is of the type
     IOConsts.ReadResults.
  *)

  (* 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 (VAR int: LONGINT);
  (* Skips leading spaces, and removes any remaining characters
     from the default input channel 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 (int: LONGINT; width: CARDINAL);
  (* Writes the value of int to the default output channel in
     text form, in a field of the given minimum width.
  *)

PROCEDURE ReadCard (VAR card: LONGCARD);
  (* Skips leading spaces, and removes any remaining characters
     from the default input channel 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 (card: LONGCARD; width: CARDINAL);
  (* Writes the value of card to the default output channel in
     text form, in a field of the given minimum width.
  *)

END SLongWholeIO.
```

4.4.49 gm2-libs-iso/SRawIO

```
DEFINITION MODULE SRawIO;

  (* Reading and writing data over default channels using raw operations, that is, with no
     conversion or interpretation. The read result is of the type IOConsts.ReadResults.
  *)

IMPORT SYSTEM;

PROCEDURE Read (VAR to: ARRAY OF SYSTEM.LOC);
  (* Reads storage units from the default input channel, and assigns them to successive
     components of to.  The read result is set to the value allRight, wrongFormat, or
     endOfInput.
  *)

PROCEDURE Write (from: ARRAY OF SYSTEM.LOC);
  (* Writes storage units to the default output channel from successive components of from.
  *)

END SRawIO.
```

4.4.50 gm2-libs-iso/SRealIO

```
DEFINITION MODULE SRealIO;

  (* Input and output of real numbers in decimal text form over
     default channels.  The read result is of the type
     IOConsts.ReadResults.
  *)

  (* The text form of a signed fixed-point real number is
       ["+" | "-"], decimal digit, {decimal digit},
       [".", {decimal digit}]

     The text form of a signed floating-point real number is
       signed fixed-point real number,
       "E", ["+" | "-"], decimal digit, {decimal digit}
  *)

PROCEDURE ReadReal (VAR real: REAL);
  (* Skips leading spaces, and removes any remaining characters
     from the default input channel that form part of a signed
     fixed or floating point number. The value of this number
     is assigned to real.  The read result is set to the value
     allRight, outOfRange, wrongFormat, endOfLine, or endOfInput.
  *)

PROCEDURE WriteFloat (real: REAL; sigFigs: CARDINAL; width: CARDINAL);
  (* Writes the value of real to the default output channel in
     floating-point text form, with sigFigs significant figures,
     in a field of the given minimum width.
  *)

PROCEDURE WriteEng (real: REAL; sigFigs: CARDINAL; width: CARDINAL);
  (* As for WriteFloat, except that 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 WriteFixed (real: REAL; place: INTEGER; width: CARDINAL);
  (* Writes the value of real to the default output channel in
     fixed-point text form, rounded to the given place relative
     to the decimal point, in a field of the given minimum width.
  *)

PROCEDURE WriteReal (real: REAL; width: CARDINAL);
  (* Writes the value of real to the default output channel, 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 SRealIO.
```

4.4.51 gm2-libs-iso/SShortIO

```
DEFINITION MODULE SShortIO;

  (* Input and output of short real numbers in decimal text form
     using default channels.  The read result is of the type
     IOConsts.ReadResults.
  *)

  (* The text form of a signed fixed-point real number is
       ["+" | "-"], decimal digit, {decimal digit},
       [".", {decimal digit}]

     The text form of a signed floating-point real number is
       signed fixed-point real number,
       "E", ["+" | "-"], decimal digit, {decimal digit}
  *)

PROCEDURE ReadReal (VAR real: SHORTREAL);
  (* Skips leading spaces, and removes any remaining characters
     from the default input channel that form part of a signed
     fixed or floating point number. The value of this number
     is assigned to real.  The read result is set to the value
     allRight, outOfRange, wrongFormat, endOfLine, or endOfInput.
  *)

PROCEDURE WriteFloat (real: SHORTREAL; sigFigs: CARDINAL;
                      width: CARDINAL);
  (* Writes the value of real to the default output channel in
     floating-point text form, with sigFigs significant figures,
     in a field of the given minimum width.
  *)

PROCEDURE WriteEng (real: SHORTREAL; sigFigs: CARDINAL;
                    width: CARDINAL);
  (* As for WriteFloat, except that 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 WriteFixed (real: SHORTREAL; place: INTEGER;
                      width: CARDINAL);
  (* Writes the value of real to the default output channel in
     fixed-point text form, rounded to the given place relative
     to the decimal point, in a field of the given minimum width.
  *)
```

```
PROCEDURE WriteReal (real: SHORTREAL; width: CARDINAL);
  (* Writes the value of real to the default output channel, 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 SShortIO.
```

4.4.52 gm2-libs-iso/SShortWholeIO

```
DEFINITION MODULE SShortWholeIO;

  (* Input and output of whole numbers in decimal text form over
     default channels.  The read result is of the type
     IOConsts.ReadResults.
  *)

  (* 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 (VAR int: SHORTINT);
  (* Skips leading spaces, and removes any remaining characters
     from the default input channel 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 (int: SHORTINT; width: CARDINAL);
  (* Writes the value of int to the default output channel in
     text form, in a field of the given minimum width.
  *)

PROCEDURE ReadCard (VAR card: SHORTCARD);
  (* Skips leading spaces, and removes any remaining characters
     from the default input channel 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 (card: SHORTCARD; width: CARDINAL);
  (* Writes the value of card to the default output channel in
     text form, in a field of the given minimum width.
  *)

END SShortWholeIO.
```

4.4.53 gm2-libs-iso/STextIO

```
DEFINITION MODULE STextIO;

  (* Input and output of character and string types over default channels. The read result
     is of the type IOConsts.ReadResults.
  *)

  (* The following procedures do not read past line marks *)

PROCEDURE ReadChar (VAR ch: CHAR);
  (* If possible, removes a character from the default input stream, and assigns the
     corresponding value to ch.  The read result is set to allRight, endOfLine or
     endOfInput.
  *)

PROCEDURE ReadRestLine (VAR s: ARRAY OF CHAR);
  (* Removes any remaining characters from the default input stream before the next line
     mark, copying to s as many as can be accommodated as a string value.  The read result
     is set to the value allRight, outOfRange, endOfLine, or endOfInput.
  *)

PROCEDURE ReadString (VAR s: ARRAY OF CHAR);
  (* Removes only those characters from the default input stream before the next line mark
     that can be accommodated in s as a string value, and copies them to s. The read result
     is set to the value allRight, endOfLine, or endOfInput.
  *)

PROCEDURE ReadToken (VAR s: ARRAY OF CHAR);
  (* Skips leading spaces, and then removes characters from the default input stream before
     the next space or line mark, copying to s as many as can be accommodated as a string
     value.  The read result is set to the value allRight, outOfRange, endOfLine, or
     endOfInput.
  *)

  (* The following procedure reads past the next line mark *)

PROCEDURE SkipLine;
  (* Removes successive items from the default input stream up to and including the next
     line mark or until the end of input is reached. The read result is set to the value
     allRight, or endOfInput.
  *)


  (* Output procedures *)

PROCEDURE WriteChar (ch: CHAR);
```

```
  (* Writes the value of ch to the default output stream. *)

PROCEDURE WriteLn;
  (* Writes a line mark to the default output stream. *)

PROCEDURE WriteString (s: ARRAY OF CHAR);
  (* Writes the string value of s to the default output stream. *)

END STextIO.
```

4.4.54 gm2-libs-iso/SWholeIO

```
DEFINITION MODULE SWholeIO;

  (* Input and output of whole numbers in decimal text form over
     default channels.  The read result is of the type
     IOConsts.ReadResults.
  *)

  (* 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 (VAR int: INTEGER);
  (* Skips leading spaces, and removes any remaining characters
     from the default input channel 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 (int: INTEGER; width: CARDINAL);
  (* Writes the value of int to the default output channel in
     text form, in a field of the given minimum width.
  *)

PROCEDURE ReadCard (VAR card: CARDINAL);
  (* Skips leading spaces, and removes any remaining characters
     from the default input channel 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 (card: CARDINAL; width: CARDINAL);
  (* Writes the value of card to the default output channel in
     text form, in a field of the given minimum width.
  *)

END SWholeIO.
```

4.4.55 gm2-libs-iso/SYSTEM

```
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 BITSPERLOC, LOCSPERWORD,
                 LOC, BYTE, WORD, ADDRESS, CSIZE_T, CSSIZE_T, COFF_T, (*
                 Target specific data types.  *)
                 ADDADR, SUBADR, DIFADR, MAKEADR, ADR, ROTATE,
                 SHIFT, CAST, TSIZE,

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

CONST
                  (* <implementation-defined constant> ; *)
  BITSPERLOC    = __ATTRIBUTE__ __BUILTIN__ ((BITS_PER_UNIT)) ;
                  (* <implementation-defined constant> ; *)
  LOCSPERWORD   = __ATTRIBUTE__ __BUILTIN__ ((UNITS_PER_WORD)) ;
                  (* <implementation-defined constant> ; *)
  LOCSPERBYTE = 8 DIV BITSPERLOC ;

(* 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.  *)

(*
   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.
```

4.4.56 gm2-libs-iso/Semaphores

```
DEFINITION MODULE Semaphores;

  (* Provides mutual exclusion facilities for use by processes. *)

TYPE
  SEMAPHORE;

PROCEDURE Create (VAR s: SEMAPHORE; initialCount: CARDINAL );
  (* Creates and returns s as the identity of a new semaphore that
     has its associated count initialized to initialCount, and has
     no processes yet waiting on it.
  *)

PROCEDURE Destroy (VAR s: SEMAPHORE);
  (* Recovers the resources used to implement the semaphore s,
     provided that no process is waiting for s to become free.
  *)

PROCEDURE Claim (s: SEMAPHORE);
  (* If the count associated with the semaphore s is non-zero,
     decrements this count and allows the calling process to
     continue; otherwise suspends the calling process until
     s is released.
  *)

PROCEDURE Release (s: SEMAPHORE);
  (* If there are any processes waiting on the semaphore s,
     allows one of them to enter the ready state; otherwise
     increments the count associated with s.
  *)

PROCEDURE CondClaim (s: SEMAPHORE): BOOLEAN;
  (* Returns FALSE if the call Claim(s) would cause the calling
     process to be suspended; in this case the count associated
     with s is not changed. Otherwise returns TRUE and the
     associated count is decremented.
  *)

END Semaphores.
```

4.4.57 gm2-libs-iso/SeqFile

```
DEFINITION MODULE SeqFile;

  (* Rewindable sequential files *)

IMPORT IOChan, ChanConsts;

TYPE
  ChanId = IOChan.ChanId;
  FlagSet = ChanConsts.FlagSet;
  OpenResults = ChanConsts.OpenResults;

  (* Accepted singleton values of FlagSet *)

CONST
  (* input operations are requested/available *)
  read = FlagSet{ChanConsts.readFlag};

  (* output operations are requested/available *)
  write = FlagSet{ChanConsts.writeFlag};

  (* a file may/must/did exist before the channel is opened *)
  old = FlagSet{ChanConsts.oldFlag};

  (* text operations are requested/available *)
  text = FlagSet{ChanConsts.textFlag};

  (* raw operations are requested/available *)
  raw = FlagSet{ChanConsts.rawFlag};

PROCEDURE OpenWrite (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 write flag is 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 at the start
     of the file (i.e. the file is of zero length).
     If a channel cannot be opened as required, the value of
     res indicates the reason, and cid identifies the invalid
     channel.
  *)

PROCEDURE OpenAppend (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 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.
```

4.4.60 gm2-libs-iso/ShortIO

```
DEFINITION MODULE ShortIO;

  (* Input and output of short real 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 fixed-point real number is
       ["+" | "-"], decimal digit, {decimal digit}, [".",
       {decimal digit}]

     The text form of a signed floating-point real number is
       signed fixed-point real number,
       "E", ["+" | "-"], decimal digit, {decimal digit}
  *)

PROCEDURE ReadReal (cid: IOChan.ChanId; VAR real: SHORTREAL);
  (* Skips leading spaces, and removes any remaining characters
     from cid that form part of a signed fixed or floating
     point number.  The value of this number is assigned to real.
     The read result is set to the value allRight, outOfRange,
     wrongFormat, endOfLine, or endOfInput.
  *)

PROCEDURE WriteFloat (cid: IOChan.ChanId; real: SHORTREAL;
                      sigFigs: CARDINAL; width: CARDINAL);
  (* Writes the value of real to cid in floating-point text form,
     with sigFigs significant figures, in a field of the given
     minimum width.
  *)

PROCEDURE WriteEng (cid: IOChan.ChanId; real: SHORTREAL;
                    sigFigs: CARDINAL; width: CARDINAL);
  (* As for WriteFloat, except that 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 WriteFixed (cid: IOChan.ChanId; real: SHORTREAL;
                      place: INTEGER; width: CARDINAL);
  (* Writes the value of real to cid in fixed-point text form,
     rounded to the given place relative to the decimal point,
     in a field of the given minimum width.
```

```
  *)

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.
```

4.4.63 gm2-libs-iso/ShortWholeIO

```
DEFINITION MODULE ShortWholeIO;

  (* 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: SHORTINT);
  (* 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: SHORTINT;
                    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: SHORTCARD);
  (* 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: SHORTCARD;
                     width: CARDINAL);
  (* Writes the value of card to cid in text form, in a field
     of the given minimum width. *)

END ShortWholeIO.
```

4.4.64 gm2-libs-iso/SimpleCipher

```
DEFINITION MODULE SimpleCipher ;

(*
    Description: provides a simple Caesar cipher layer which
                 can be attached to any channel device.  This,
                 pedagogical, module is designed to show how
                 it is possible to add further layers underneath
                 the channel devices.
*)

FROM IOChan IMPORT ChanId ;


(*
   InsertCipherLayer - inserts a caesar cipher below channel, cid.
                       The encryption, key, is specified.
*)

PROCEDURE InsertCipherLayer (cid: ChanId; key: INTEGER) ;


(*
   RemoveCipherLayer - removes a Caesar cipher below channel, cid.
*)

PROCEDURE RemoveCipherLayer (cid: ChanId) ;


END SimpleCipher.
```

4.4.65 gm2-libs-iso/StdChans

```
DEFINITION MODULE StdChans;

  (* Access to standard and default channels *)

IMPORT IOChan;

TYPE
  ChanId = IOChan.ChanId;
    (* Values of this type are used to identify channels *)

  (* The following functions return the standard channel values.
     These channels cannot be closed.
  *)

PROCEDURE StdInChan (): ChanId;
  (* Returns the identity of the implementation-defined standard source for
program
     input.
  *)

PROCEDURE StdOutChan (): ChanId;
  (* Returns the identity of the implementation-defined standard source for program
     output.
  *)

PROCEDURE StdErrChan (): ChanId;
  (* Returns the identity of the implementation-defined standard destination for program
     error messages.
  *)

PROCEDURE NullChan (): ChanId;
  (* Returns the identity of a channel open to the null device. *)

  (* The following functions return the default channel values *)

PROCEDURE InChan (): ChanId;
  (* Returns the identity of the current default input channel. *)

PROCEDURE OutChan (): ChanId;
  (* Returns the identity of the current default output channel. *)

PROCEDURE ErrChan (): ChanId;
  (* Returns the identity of the current default error message channel. *)

  (* The following procedures allow for redirection of the default channels *)
```

```
PROCEDURE SetInChan (cid: ChanId);
  (* Sets the current default input channel to that identified by cid. *)

PROCEDURE SetOutChan (cid: ChanId);
  (* Sets the current default output channel to that identified by cid. *)

PROCEDURE SetErrChan (cid: ChanId);
  (* Sets the current default error channel to that identified by cid. *)

END StdChans.
```

4.4.66 gm2-libs-iso/Storage

```
DEFINITION MODULE Storage;

  (* Facilities for dynamically allocating and deallocating storage *)

IMPORT SYSTEM;

PROCEDURE ALLOCATE (VAR addr: SYSTEM.ADDRESS; amount: CARDINAL);
  (* Allocates storage for a variable of size amount and assigns
     the address of this variable to addr. If there is insufficient
     unallocated storage to do this, the value NIL is assigned to addr.
  *)

PROCEDURE DEALLOCATE (VAR addr: SYSTEM.ADDRESS; amount: CARDINAL);
  (* Deallocates amount locations allocated by ALLOCATE for
     the storage of the variable addressed by addr and assigns
     the value NIL to addr.
  *)

PROCEDURE REALLOCATE (VAR addr: SYSTEM.ADDRESS; amount: CARDINAL);
  (* Attempts to reallocate, amount of storage.  Effectively it
     calls ALLOCATE, copies the amount of data pointed to by
     addr into the new space and DEALLOCATES the addr.
     This procedure is a GNU extension.
  *)

TYPE
  StorageExceptions = (
    nilDeallocation,             (* first argument to DEALLOCATE is NIL *)
    pointerToUnallocatedStorage, (* storage to deallocate not allocated by ALLOCATE *)
    wrongStorageToUnallocate     (* amount to deallocate is not amount allocated *)
  );

PROCEDURE IsStorageException (): BOOLEAN;
  (* Returns TRUE if the current coroutine is in the exceptional
     execution state because of the raising of an exception from
     StorageExceptions; otherwise returns FALSE.
  *)

PROCEDURE StorageException (): StorageExceptions;
  (* If the current coroutine is in the exceptional execution
     state because of the raising of an exception from
     StorageExceptions, returns the corresponding
     enumeration value, and otherwise raises an exception.
  *)
```

```
END Storage.
```

4.4.67 gm2-libs-iso/StreamFile

```
DEFINITION MODULE StreamFile;

  (* Independent sequential data streams *)

IMPORT IOChan, ChanConsts;

TYPE
  ChanId = IOChan.ChanId;
  FlagSet = ChanConsts.FlagSet;
  OpenResults = ChanConsts.OpenResults;

  (* Accepted singleton values of FlagSet *)

CONST
  read = FlagSet{ChanConsts.readFlag};   (* input operations are requested/available *)
  write = FlagSet{ChanConsts.writeFlag}; (* output operations are requested/available *)
  old = FlagSet{ChanConsts.oldFlag};     (* a file may/must/did exist before the channel is
                                            opened *)
  text = FlagSet{ChanConsts.textFlag};   (* text operations are requested/available *)
  raw = FlagSet{ChanConsts.rawFlag};     (* raw operations are requested/available *)


PROCEDURE Open (VAR cid: ChanId; name: ARRAY OF CHAR;
                flags: FlagSet; VAR res: OpenResults);
  (* Attempts to obtain and open a channel connected to a
     sequential stream of the given name.
     The read flag implies old; without the raw flag, text is
     implied.  If successful, assigns to cid the identity of
     the opened channel, and assigns the value opened to res.
     If a channel cannot be opened as required, the value of
     res indicates the reason, and cid identifies the invalid
     channel.
  *)

PROCEDURE IsStreamFile (cid: ChanId): BOOLEAN;
  (* Tests if the channel identified by cid is open to a sequential stream. *)

PROCEDURE Close (VAR cid: ChanId);
  (* If the channel identified by cid is not open to a sequential stream, the exception
     wrongDevice is raised; otherwise closes the channel, and assigns the value identifying
     the invalid channel to cid.
  *)

END StreamFile.
```

4.4.68 gm2-libs-iso/StringChan

```
DEFINITION MODULE StringChan ;

(*
    Description: provides a set of Channel and String
                 input and output procedures.
*)

FROM DynamicStrings IMPORT String ;
IMPORT IOChan;


(*
   writeString - writes a string, s, to ChanId, cid.
                 The string, s, is not destroyed.
*)

PROCEDURE writeString (cid: IOChan.ChanId; s: String) ;


(*
   writeFieldWidth - writes a string, s, to ChanId, cid.
                     The string, s, is not destroyed and it
                     is prefixed by spaces so that at least,
                     width, characters are written.  If the
                     string, s, is longer than width then
                     no spaces are prefixed to the output
                     and the entire string is written.
*)

PROCEDURE writeFieldWidth (cid: IOChan.ChanId;
                           s: String; width: CARDINAL) ;


END StringChan.
```

4.4.69 gm2-libs-iso/Strings

```
DEFINITION MODULE Strings;

  (* Facilities for manipulating strings *)

TYPE
  String1 = ARRAY [0..0] OF CHAR;
    (* String1 is provided for constructing a value of a single-character string type from a
       single character value in order to pass CHAR values to ARRAY OF CHAR parameters.
    *)

PROCEDURE Length (stringVal: ARRAY OF CHAR): CARDINAL;
  (* Returns the length of stringVal (the same value as would be returned by the
     pervasive function LENGTH).
  *)


(* The following seven procedures construct a string value, and attempt to assign it to a
   variable parameter.  They all have the property that if the length of the constructed string
   value exceeds the capacity of the variable parameter, a truncated value is assigned, while
   if the length of the constructed string value is less than the capacity of the variable
   parameter, a string terminator is appended before assignment is performed.
*)

PROCEDURE Assign (source: ARRAY OF CHAR; VAR destination: ARRAY OF CHAR);
  (* Copies source to destination *)

PROCEDURE Extract (source: ARRAY OF CHAR; startIndex, numberToExtract: CARDINAL;
                   VAR destination: ARRAY OF CHAR);
  (* Copies at most numberToExtract characters from source to destination, starting at position
     startIndex in source.
  *)

PROCEDURE Delete (VAR stringVar: ARRAY OF CHAR; startIndex, numberToDelete:
CARDINAL);
  (* Deletes at most numberToDelete characters from stringVar, starting at position
     startIndex.
  *)

PROCEDURE Insert (source: ARRAY OF CHAR; startIndex: CARDINAL;
                  VAR destination: ARRAY OF CHAR);
  (* Inserts source into destination at position startIndex *)

PROCEDURE Replace (source: ARRAY OF CHAR; startIndex: CARDINAL;
                   VAR destination: ARRAY OF CHAR);
  (* Copies source into destination, starting at position startIndex. Copying stops when
```

```
     all of source has been copied, or when the last character of the string value in
     destination has been replaced.
  *)

PROCEDURE Append (source: ARRAY OF CHAR; VAR destination: ARRAY OF CHAR);
  (* Appends source to destination. *)

PROCEDURE Concat (source1, source2: ARRAY OF CHAR; VAR destination: ARRAY OF CHAR);
  (* Concatenates source2 onto source1 and copies the result into destination. *)

(* The following predicates provide for pre-testing of the operation-completion
   conditions for the procedures above.
*)

PROCEDURE CanAssignAll (sourceLength: CARDINAL; VAR destination: ARRAY OF CHAR): BOOLEAN;
  (* Returns TRUE if a number of characters, indicated by sourceLength, will fit into
     destination; otherwise returns FALSE.
  *)

PROCEDURE CanExtractAll (sourceLength, startIndex, numberToExtract: CARDINAL;
                         VAR destination: ARRAY OF CHAR): BOOLEAN;
  (* Returns TRUE if there are numberToExtract characters starting at startIndex and
     within the sourceLength of some string, and if the capacity of destination is
     sufficient to hold numberToExtract characters; otherwise returns FALSE.
  *)

PROCEDURE CanDeleteAll (stringLength, startIndex, numberToDelete: CARDINAL): BOOLEAN;
  (* Returns TRUE if there are numberToDelete characters starting at startIndex and
     within the stringLength of some string; otherwise returns FALSE.
  *)

PROCEDURE CanInsertAll (sourceLength, startIndex: CARDINAL;
                        VAR destination: ARRAY OF CHAR): BOOLEAN;
  (* Returns TRUE if there is room for the insertion of sourceLength characters from
     some string into destination starting at startIndex; otherwise returns FALSE.
  *)

PROCEDURE CanReplaceAll (sourceLength, startIndex: CARDINAL;
                         VAR destination: ARRAY OF CHAR): BOOLEAN;
  (* Returns TRUE if there is room for the replacement of sourceLength characters in
     destination starting at startIndex; otherwise returns FALSE.
  *)

PROCEDURE CanAppendAll (sourceLength: CARDINAL; VAR destination: ARRAY OF CHAR): BOOLEAN;
  (* Returns TRUE if there is sufficient room in destination to append a string of
     length sourceLength to the string in destination; otherwise returns FALSE.
  *)
```

```
PROCEDURE CanConcatAll (source1Length, source2Length: CARDINAL;
                        VAR destination: ARRAY OF CHAR): BOOLEAN;
  (* Returns TRUE if there is sufficient room in destination for a two strings of
     lengths source1Length and source2Length; otherwise returns FALSE.
  *)

(* The following type and procedures provide for the comparison of string values, and for the
   location of substrings within strings.
*)

TYPE
  CompareResults = (less, equal, greater);

PROCEDURE Compare (stringVal1, stringVal2: ARRAY OF CHAR): CompareResults;
  (* Returns less, equal, or greater, according as stringVal1 is lexically less than,
     equal to, or greater than stringVal2.
  *)

PROCEDURE Equal (stringVal1, stringVal2: ARRAY OF CHAR): BOOLEAN;
  (* Returns Strings.Compare(stringVal1, stringVal2) = Strings.equal *)

PROCEDURE FindNext (pattern, stringToSearch: ARRAY OF CHAR; startIndex: CARDINAL;
                    VAR patternFound: BOOLEAN; VAR posOfPattern: CARDINAL);
  (* Looks forward for next occurrence of pattern in stringToSearch, starting the search at
     position startIndex. If startIndex < LENGTH(stringToSearch) and pattern is found,
     patternFound is returned as TRUE, and posOfPattern contains the start position in
     stringToSearch of pattern. Otherwise patternFound is returned as FALSE, and posOfPattern
     is unchanged.
  *)

PROCEDURE FindPrev (pattern, stringToSearch: ARRAY OF CHAR; startIndex: CARDINAL;
                    VAR patternFound: BOOLEAN; VAR posOfPattern: CARDINAL);
  (* Looks backward for the previous occurrence of pattern in stringToSearch and returns the
     position of the first character of the pattern if found. The search for the pattern
     begins at startIndex. If pattern is found, patternFound is returned as TRUE, and
     posOfPattern contains the start position in stringToSearch of pattern in the range
     [0..startIndex]. Otherwise patternFound is returned as FALSE, and posOfPattern is unchanged.
  *)

PROCEDURE FindDiff (stringVal1, stringVal2: ARRAY OF CHAR;
                    VAR differenceFound: BOOLEAN; VAR posOfDifference: CARDINAL);
  (* Compares the string values in stringVal1 and stringVal2 for differences. If they
     are equal, differenceFound is returned as FALSE, and TRUE otherwise. If
     differenceFound is TRUE, posOfDifference is set to the position of the first
     difference; otherwise posOfDifference is unchanged.
  *)
```

```
PROCEDURE Capitalize (VAR stringVar: ARRAY OF CHAR);
  (* Applies the function CAP to each character of the string value in stringVar. *)


END Strings.
```

4.4.70 gm2-libs-iso/SysClock

```
DEFINITION MODULE SysClock;

(* Facilities for accessing a system clock that records the date
   and time of day *)

CONST
  maxSecondParts = 1000000 ;

TYPE
  Month    = [1 .. 12];
  Day      = [1 .. 31];
  Hour     = [0 .. 23];
  Min      = [0 .. 59];
  Sec      = [0 .. 59];
  Fraction = [0 .. maxSecondParts];
  UTCDiff  = [-780 .. 720];
  DateTime =
    RECORD
      year:      CARDINAL;
      month:     Month;
      day:       Day;
      hour:      Hour;
      minute:    Min;
      second:    Sec;
      fractions: Fraction;      (* parts of a second *)
      zone:      UTCDiff;       (* Time zone differential
                                   factor which is the number
                                   of minutes to add to local
                                   time to obtain UTC. *)
      summerTimeFlag: BOOLEAN;  (* Interpretation of flag
                                   depends on local usage. *)
    END;

PROCEDURE CanGetClock(): BOOLEAN;
(* Tests if the clock can be read *)

PROCEDURE CanSetClock(): BOOLEAN;
(* Tests if the clock can be set *)

PROCEDURE IsValidDateTime(userData: DateTime): BOOLEAN;
(* Tests if the value of userData is a valid *)

PROCEDURE GetClock(VAR userData: DateTime);
(* Assigns local date and time of the day to userData *)
```

```
PROCEDURE SetClock(userData: DateTime);
(* Sets the system time clock to the given local date and
   time *)

END SysClock.
```

4.4.71 gm2-libs-iso/TERMINATION

```
DEFINITION MODULE TERMINATION;

(* Provides facilities for enquiries concerning the occurrence of termination events. *)

PROCEDURE IsTerminating (): BOOLEAN ;
  (* Returns true if any coroutine has started  program termination and false otherwise. *)

PROCEDURE HasHalted (): BOOLEAN ;
  (* Returns true if a call to HALT has been made and false otherwise. *)

END TERMINATION.
```

4.4.72 gm2-libs-iso/TermFile

```
DEFINITION MODULE TermFile;

  (* Access to the terminal device *)

  (* Channels opened by this module are connected to a single
     terminal device; typed characters are distributed between
     channels according to the sequence of read requests.
  *)

IMPORT IOChan, ChanConsts;

TYPE
  ChanId = IOChan.ChanId;
  FlagSet = ChanConsts.FlagSet;
  OpenResults = ChanConsts.OpenResults;

  (* Accepted singleton values of FlagSet *)

CONST
  read = FlagSet{ChanConsts.readFlag};
  (* input operations are requested/available *)
  write = FlagSet{ChanConsts.writeFlag};
  (* output operations are requested/available *)
  text = FlagSet{ChanConsts.textFlag};
  (* text operations are requested/available *)
  raw = FlagSet{ChanConsts.rawFlag};
  (* raw operations are requested/available *)
  echo = FlagSet{ChanConsts.echoFlag};
  (* echoing by interactive device on reading of
     characters from input stream requested/applies
  *)

PROCEDURE Open (VAR cid: ChanId; flagset: FlagSet; VAR res: OpenResults);
  (* Attempts to obtain and open a channel connected to
     the terminal.  Without the raw flag, text is implied.
     Without the echo flag, line mode is requested,
     otherwise single character mode is requested.
     If successful, assigns to cid the identity of
     the opened channel, and assigns the value opened to res.
     If a channel cannot be opened as required, the value of
     res indicates the reason, and cid identifies the
     invalid channel.
  *)

PROCEDURE IsTermFile (cid: ChanId): BOOLEAN;
```

```
  (* Tests if the channel identified by cid is open to
     the terminal. *)

PROCEDURE Close (VAR cid: ChanId);
  (* If the channel identified by cid is not open to the terminal,
     the exception wrongDevice is raised; otherwise closes the
     channel and assigns the value identifying the invalid channel
     to cid.
  *)

END TermFile.
```

4.4.73 gm2-libs-iso/TextIO

```
DEFINITION MODULE TextIO;

  (* Input and output of character and string types over
     specified channels.  The read result is of the type
     IOConsts.ReadResults.
  *)

IMPORT IOChan;

  (* The following procedures do not read past line marks *)

PROCEDURE ReadChar (cid: IOChan.ChanId; VAR ch: CHAR);
  (* If possible, removes a character from the input stream
     cid and assigns the corresponding value to ch.  The
     read result is set to the value allRight, endOfLine, or
     endOfInput.
  *)

PROCEDURE ReadRestLine (cid: IOChan.ChanId; VAR s: ARRAY OF CHAR);
  (* Removes any remaining characters from the input stream
     cid before the next line mark,  copying to s as many as
     can be accommodated as a string value.  The read result is
     set to the value allRight, outOfRange, endOfLine, or
     endOfInput.
  *)

PROCEDURE ReadString (cid: IOChan.ChanId; VAR s: ARRAY OF CHAR);
  (* Removes only those characters from the input stream cid
     before the next line mark that can be accommodated in s
     as a string value, and copies them to s.  The read result
     is set to the value allRight, endOfLine, or endOfInput.
  *)

PROCEDURE ReadToken (cid: IOChan.ChanId; VAR s: ARRAY OF CHAR);
  (* Skips leading spaces, and then removes characters from
     the input stream cid before the next space or line mark,
     copying to s as many as can be accommodated as a string
     value.  The read result is set to the value allRight,
     outOfRange, endOfLine, or endOfInput.
  *)

  (* The following procedure reads past the next line mark *)

PROCEDURE SkipLine (cid: IOChan.ChanId);
  (* Removes successive items from the input stream cid up
```

```
      to and including the next line mark, or until the end
      of input is reached.  The read result is set to the
      value allRight, or endOfInput.
   *)

   (* Output procedures *)

 PROCEDURE WriteChar (cid: IOChan.ChanId; ch: CHAR);
   (* Writes the value of ch to the output stream cid. *)

 PROCEDURE WriteLn (cid: IOChan.ChanId);
   (* Writes a line mark to the output stream cid. *)

 PROCEDURE WriteString (cid: IOChan.ChanId; s: ARRAY OF CHAR);
   (* Writes the string value in s to the output stream cid. *)

 END TextIO.
```

4.4.74 gm2-libs-iso/TextUtil

```
DEFINITION MODULE TextUtil ;

(*
    Description: provides text manmipulation routines.
*)

IMPORT IOChan ;


(*
   SkipSpaces - skips any spaces.
*)

PROCEDURE SkipSpaces (cid: IOChan.ChanId) ;


(* CharAvailable returns TRUE if IOChan.ReadResult is notKnown or
   allRight.  *)

PROCEDURE CharAvailable (cid: IOChan.ChanId) : BOOLEAN ;


(* EofOrEoln returns TRUE if IOChan.ReadResult is endOfLine or
   endOfInput.  *)

PROCEDURE EofOrEoln (cid: IOChan.ChanId) : BOOLEAN ;


END TextUtil.
```

4.4.75 gm2-libs-iso/WholeConv

```
DEFINITION MODULE WholeConv;

  (* Low-level whole-number/string conversions *)

IMPORT
  ConvTypes;

TYPE
  ConvResults = ConvTypes.ConvResults;
        (* strAllRight, strOutOfRange, strWrongFormat, strEmpty *)

PROCEDURE ScanInt (inputCh: CHAR;
                   VAR chClass: ConvTypes.ScanClass;
                   VAR nextState: ConvTypes.ScanState) ;
  (* Represents the start state of a finite state scanner for signed
     whole numbers - assigns class of inputCh to chClass and a
     procedure representing the next state to nextState.
  *)

PROCEDURE FormatInt (str: ARRAY OF CHAR): ConvResults;
  (* Returns the format of the string value for conversion to INTEGER. *)

PROCEDURE ValueInt (str: ARRAY OF CHAR): INTEGER;
  (* Returns the value corresponding to the signed whole number string
     value str if str is well-formed; otherwise raises the WholeConv
     exception.
   *)

PROCEDURE LengthInt (int: INTEGER): CARDINAL;
  (* Returns the number of characters in the string representation of
     int.
   *)

PROCEDURE ScanCard (inputCh: CHAR; VAR chClass: ConvTypes.ScanClass;
                    VAR nextState: ConvTypes.ScanState);
  (* Represents the start state of a finite state scanner for unsigned
     whole numbers - assigns class of inputCh to chClass and a procedure
     representing the next state to nextState.
   *)

PROCEDURE FormatCard (str: ARRAY OF CHAR): ConvResults;
  (* Returns the format of the string value for conversion to CARDINAL.
   *)

PROCEDURE ValueCard (str: ARRAY OF CHAR): CARDINAL;
```

```
  (* 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.
```

4.4.76 gm2-libs-iso/WholeIO

```
DEFINITION MODULE WholeIO;

  (* 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: INTEGER);
  (* 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: INTEGER;
                    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: CARDINAL);
  (* 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: CARDINAL;
                     width: CARDINAL);
  (* Writes the value of card to cid in text form, in a field
     of the given minimum width. *)

END WholeIO.
```

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.
*)
```

```
PROCEDURE isdst () : INTEGER ;


(*
   tzname - returns the string associated with the local timezone.
            The daylight value is 0 or 1.  The value 0 returns the non
            daylight saving timezone string and the value of 1 returns
            the daylight saving timezone string.
*)

PROCEDURE tzname (daylight: INTEGER) : ADDRESS ;


(*
   InitTimespec - returns a newly created opaque type.
*)

PROCEDURE InitTimespec () : timespec ;


(*
   KillTimespec - deallocates the memory associated with an
                  opaque type.
*)

PROCEDURE KillTimespec (tv: timespec) : timespec ;


(*
   GetTimespec - retrieves the number of seconds and nanoseconds
                 from the timespec.  A return value of 0 means timespec
                 is unavailable and a return value of 1 indicates success.
*)

PROCEDURE GetTimespec (ts: timespec; VAR sec, nano: LONGCARD) : INTEGER ;


(*
   SetTimespec - sets the number of seconds and nanoseconds
                 into timespec.  A return value of 0 means timespec
                 is unavailable and a return value of 1 indicates success.
*)

PROCEDURE SetTimespec (ts: timespec; sec, nano: LONGCARD) : INTEGER ;
```

```
(*
   GetTimeRealtime - performs return gettime (CLOCK_REALTIME, ts).
                     gettime returns 0 on success and -1 on failure.
                     If the underlying system does not have gettime
                     then GetTimeRealtime returns 1.
*)

PROCEDURE GetTimeRealtime (ts: timespec) : INTEGER ;


(*
   SetTimeRealtime - performs return settime (CLOCK_REALTIME, ts).
                     gettime returns 0 on success and -1 on failure.
                     If the underlying system does not have gettime
                     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 primatives.
*)

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.
```

4.5 Indices

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