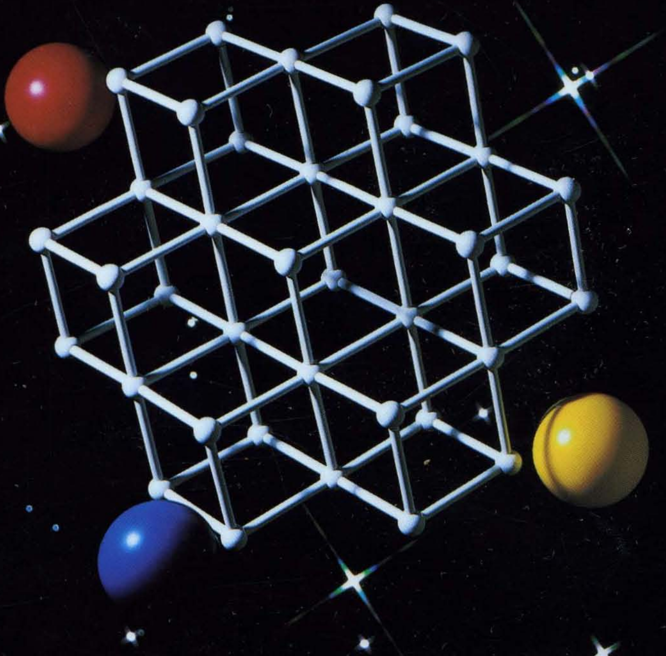
LOGITECH™ MODULA-2 VERSION 3.0



USER'S MANUAL

LOGITECH™ MODULA-2

Version 3.0

USER'S MANUAL

This edition applies to ***LOGITECH Modula-2, Version 3.00.***

Third Edition September 1987

Document #:	LU-UD-009-1
Initial issue:	February 1984
Current revision:	August 1987
Printed:	August 1987

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LOGITECH MODULA-2

Introduction

IMPORTANT

See the READ.ME file on **Disk 1** for late breaking news about this version of *LOGITECH Modula-2* .

How LOGITECH Modula-2 is Organized

This manual assumes that you are familiar with the basics of *DOS* and with basic programming concepts and terminology.

If you are a beginner, work through the tutorial to familiarize yourself with *LOGITECH Modula-2*. Then consult the bibliography in **Appendix** A, for books on *Modula-2*.

If you are more experienced, and perhaps familiar with *Modula-2*'s predecessor, **Pascal**, read through Chapter 2, Modula-2 for the Pascal Programmer for an introduction to the implementation-specific features of *LOGITECH Modula-2*, and later as a reference for specific questions and problems which may arise.

This manual features:

- Introductory information which includes system requirements and installation instructions.
- A step-by-step tutorial through the system, with the *POINT Editor* connecting you to the various parts of the *LOGITECH Modula-2* world.
- An overview of **Modula-2**, which explains how it differs from and is similar to **Pascal**, with primary features of the language.
- Complete instructions for the *LOGITECH Compiler*.
- Complete instructions for the *LOGITECH Symbolic Post-Mortem Debugger*.
- Information on version checking for orderly program development.
- How to use non-*Modula-2* modules in *LOGITECH Modula-2* programs.
- A description of **Modula-2** implementation features.
- How to help *LOGITECH Modula-2* utilities find Library information.
- A complete listing of the *LOGITECH Modula-2* .DEF files, with a cross-referenced index.
- Information on memory organization and run-time organization.
- Technical tips.
- A bibliography.
- A *LOGITECH Modula-2* glossary.
- An index.

How to Read This Manual

The following conventions are used in this manual:

Keys to be pressed, look like this:

[Y] [Esc] [↵]

Control sequences or characters entered with a **Control** or **Shift** key, look like this:

[Ctrl]-[C] [Ctrl]-[Break] [⇑Shift]-[F2] [Alt]-[X]

Keys from the **Numeric Keypad** are shown like this:

[↑] [↓] [←] [→]

[PgUp] [PgDn] [+] [−]

Keyboard input for the ***DOS*** Command line is in upper case and looks like this:

M2L [↵]

Mouse buttons used are based on the ***LOGITECH*** standard, and use three buttons, e.g,

[■ ❑ ❑] means press the left mouse button,
[❑ ❑ ■] means press the right mouse button, and
[❑ ■ ❑] means press the middle mouse button.

[■ ■] means press both buttons on a two button mouse.

Variable names in the text are surrounded by angle brackets, as in

<Application name> [↵]

File names look like this:

M2L.EXE

DOS commands and statements look like this:

PATH, COPY

Product names look like this:

MS DOS, LOGITECH Modula 2

Reserved words, predefined functions, and user-defined functions in **LOGITECH** ***Modula-2*** look like this when being discussed in text:

PROCESS, VAL, MyFunction

These are not emphasized in screen display or program listings.

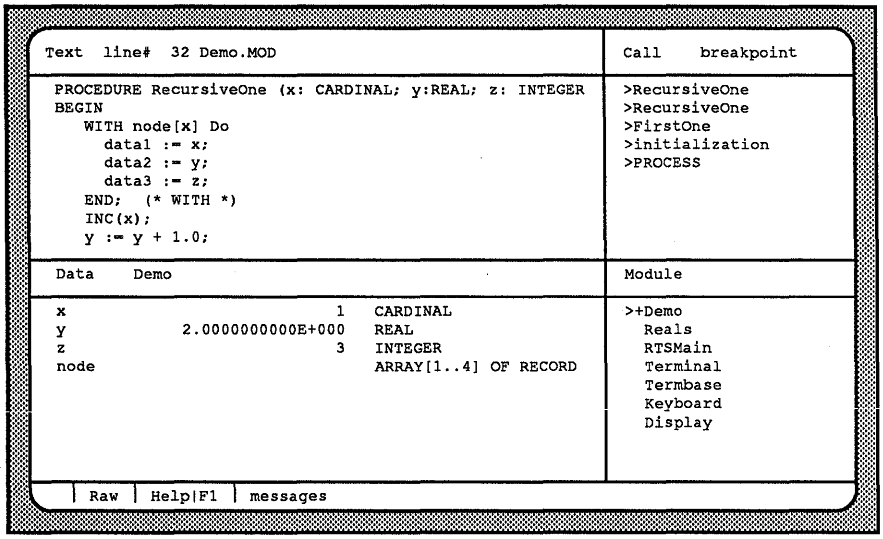
Screen output and some listings look like this:

```
Program Not Found
```

Program source code looks like this:

```
IF condition THEN
   statement6;
ELSIF condition THEN
   statement7;
ELSE
   statement8;
END;
```

Sample Screens look like this:



```
Text  line#  32 Demo.MOD                                   Call    breakpoint

PROCEDURE RecursiveOne (x: CARDINAL; y:REAL; z: INTEGER    >RecursiveOne
BEGIN                                                      >RecursiveOne
   WITH node[x] Do                                         >FirstOne
     data1 := x;                                           >initialization
     data2 := y;                                           >PROCESS
     data3 := z;
   END;  (* WITH *)
   INC(x);
   y := y + 1.0;

Data    Demo                                               Module

x                             1   CARDINAL                 >+Demo
y             2.0000000000E+000   REAL                       Reals
z                             3   INTEGER                    RTSMain
node                              ARRAY[1..4] OF RECORD      Terminal
                                                             Termbase
                                                             Keyboard
                                                             Display

   | Raw | Help|F1 | messages
```

LOGITECH POLICIES AND SERVICES

We know that effective communication with our customers is the key to quality service. Therefore we have set up the **LMIS** (LOGITECH **M**ouse **I**nformation **S**ervice), an electronic bulletin board where you can contact us at *your* convenience. To reach the **LMIS**, dial:

(415) 795-0408

using a 300, 1200 or 2400 baud modem.

The menu of available options is self explanatory.

LOGITECH also sponsors an electronic conference on ***BIX***, the **B**YTE **I**NFORMATION E**X**CHANGE system from ***Byte*** magazine. If you have access to ***BIX***, join us in

conference **LOGITECH**,

and communicate with us there.

For all ***LOGITECH Modula-2*** users, including **ISVs** (Independent Software Vendors), we have formed a **LOGITECH Modula-2 User Group**. **LOGIMUG** publishes a newsletter and provides a forum through which ***LOGITECH Modula-2*** users can exchange ideas and information. If you are an **ISV**, we encourage you to join the impressive list of developers who use ***LOGITECH Modula-2*** to design application software. Call us for details.

The **Modula-2 User Association** (MODUS) is another important source of information about the language, as well as a forum for ***Modula-2*** users to exchange ideas and to share pertinent technical tips. **LOGITECH** is an active corporate member of this association. We encourage you to contact MODUS at:

MODUS
P.O Box 51778
Palo Alto, California 94303

(415) 322-0547

Other LOGITECH Products

At **LOGITECH** we pride ourselves on technical excellence and advanced engineering. In addition to *LOGITECH Modula-2*, we also offer these fine products which we believe to be the most advanced in their product category.

LOGITECH Modula-2 Toolkit

The *LOGITECH Modula-2 Toolkit* offers these **Modula-2** functions:

- *M2FORMAT*, the *LOGITECH Modula-2* source code formatter.
- The *LOGITECH Linker*, the optimal linker for *LOGITECH Modula-2*.
- The *LOGITECH RTD*, or Symbolic Run-Time Debugger.
- *M2DECODE* dissambles .OBJ files for *LOGITECH Modula-2* code.
- *M2VERS* keeps track of *LOGITECH Modula-2* development versions.
- *M2XREWF* generates cross-referenced tables of Modula-2 source files.
- *M2MAKE* creates batch files with all parameters and search strategies needed to recompile and relink changes made to your source code.
- *M2CHECK* helps you streamline code by referencing unused or questionable library items.

Other LOGITECH Modula-2 Utilities

- The *LOGITECH Turbo-Pascal To Modula-2 Translator.*
- A *VAX/VMS version* of *LOGITECH Modula-2*.

Site licences are available for all *LOGITECH Modula-2* products.

The LOGITECH C7 Mouse

The **LOGITECH** *C7* **Mouse** connects to a serial port in your computer. It needs no pad and no external power supply.

The LOGITECH Bus Mouse

The **LOGITECH Bus Mouse** is equivalent to the *LOGITECH C7 Mouse*, except that it is connected to a Bus Board which you insert in your computer. It needs no pad and no external power supply.

For additional information, or to order these products, call the **LOGITECH** sales office toll-free from anywhere in the **continental U.S.** at **(800)231-7717**, or in **California**, call **(800) 552-8885.**

Installation

This chapter tells you how to install the ***LOGITECH Modula-2 Development System*** under ***DOS***, as well as how to optimize the system for your use.

Instructions are given for installation to a set of floppy diskettes, as well as to a hard disk. In addition, this chapter tells you which floppy diskette to use while developing your programs on a floppy diskette system.

Help in the form of batch files is provided on **Disk 1**. You can modify these batch files, or install the system manually if your system differs from the assumed standard.

NOTE

Remember to read the READ.ME file on **Disk #1** for late breaking information that may not have been available when this manual went to press.

What do you need?

LOGITECH Modula-2 runs on an *IBM PC, XT, AT* or compatible computers, with:

- A floppy disk drive **A**, and either
    - A floppy disk drive **B**, or
    - A hard disk drive **C**.

In addition:

- To run M2C.EXE (the **fully-linked version** of the compiler), you must have **512 K Bytes** of RAM memory.

- To run M2COMP.EXE (the **overlay version** of the compiler), you must have **290 K Bytes** of RAM memory.

What have you purchased?

Manuals

If you purchased *LOGITECH Modula-2* by itself, you have a copy of the *POINT Editor User's Manual*, in addition to the *LOGITECH Modula-2 User's Manual* you are now reading.

If you purchased the *LOGITECH Modula-2 Development System*, then you also have a copy of the *LOGITECH Modula-2 Toolkit Manual.*

Diskettes

If you purchased *LOGITECH Modula-2* by itself, you received five diskettes

Disk 1:	**POINT Editor**
Disk 2:	**Standard Library**
Disk 3:	**Fully-Linked Compiler**
Disk 4:	**Overlay Compiler**
Disk 5:	**Post-Mortem Debugger**

If you purchased the *LOGITECH Modula-2 Development System* which includes the *LOGITECH Modula-2 Toolkit*, you also received four additional diskettes:

Disk 1:	**Standard Library Sources I** **Utilities I**
Disk 2:	**Standard Library Sources II**
Disk 3:	**Linker** **Utilities II**
Disk 4:	**Run-Time Debugger**

Configure Your Operating System

In order to run *LOGITECH Modula-2*, you need to configure your operating system. This is done by setting up the CONFIG.SYS file on the disk from which you start your operating system. The INSTALL procedure makes the necessary additions with the proper settings to your CONFIG.SYS file, and saves the backup file as CONFIG.OLD. Then it tells you how to enlarge your environment space, according to the version of *DOS* you are using.

`FILES=20`	The number of files that can be open at the same time. A value of **twenty** (20) or more is needed to operate the *LOGITECH Modula-2 Development System.* If the right number of files is not set in *DOS*, the error message `file not found` will appear when you try to run *LOGITECH Modula-2*. This means that even though the file you want may be present on the disk, it can't be opened due to a lack of **file descriptors** in the operating system.
`BUFFERS=20`	We recommend that you set the number of buffers to **twenty** (20). An appropriate value will increase the performance of the *LOGITECH Modula-2* system. However, this is not a requirement and you may omit this statement.
`DEVICE=ANSI.SYS`	This statement provides access to *Extended Screen and Keyboard Control* provided by *DOS*. Some parts of *LOGITECH Modula-2* assume that this driver is used. If you omit this statement in CONFIG.SYS, certain control characters written to the display may not have the effect specified in the **Terminal** definition module.

`SHELL=COMMAND.COM/P/E:`*`n`* (for *DOS* 3.1 and higher)

Whenever you start your computer, *DOS* allocates a small amount of bytes (e.g., 160) for environment space. Often, this is not enough for the ***LOGITECH Modula-2*** settings.

An additional line in your CONFIG.SYS file can correct this:

```
SHELL=COMMAND.COM/P/E:n
```

If you are using ***DOS 3.1*** or ***DOS 3.2***, add one of these lines:

- For ***DOS 3.1***, ***n*** is the ***number of 16 byte paragraphs*** allocated for environment space. We recommend that you add this line:

  ```
  SHELL=COMMAND.COM/P/E:31
  ```

- For *DOS 3.2* or higher, ***n*** is the ***number of bytes*** allocated for environment space. We recommend:

  ```
  SHELL=COMMAND.COM/P/E:500
  ```

REMEMBER

After you create or change your CONFIG.SYS file, you must restart your system for the changes to take effect.

LOGITECH Modula-2 on Floppy Diskettes

NOTE

Before you install your software to either floppy drive or hard disk system, we strongly recommend that you take a minute to:

1) Put Write-Protect tabs on all your *LOGITECH Modula-2* diskettes, and

2) Use the **DISKCOPY** and **DISKCOMP** commands from your *DOS* files to back up your diskettes. Then put your original diskettes in an archival area and use the copies for all installation.

3) Prepare formatted diskettes with readable labeling, before you copy the the files in the Installation procedure which follows.

Installing on Floppy Diskettes

If your *LOGITECH Modula-2 Development System* is going to be installed on a dual floppy system, we recommend this organization:

Step 1: Prepare a POINT Editor diskette for your Modula-2 system.

Insert the *LOGITECH Modula-2* **POINT Editor (Disk #1)** into drive **B**, and an empty, formatted disk into drive A. Type,

```
COPY B:PT*.*        A:   ↵
COPY B:CHECKER.*    A:   ↵
COPY B:M2ASSIST.*   A:   ↵
```

This will provide you with the **LOGITECH** editing environment of choice for your *LOGITECH Modula-2 Development System.*

Step 2: Prepare a Library diskette for your Modula-2 system.

Insert the *LOGITECH Modula-2* **Library (Disk #2)** into drive **B**, and an empty, formatted disk into drive A. Type,

```
COPY B:*.*          A:   ↵
```

You will use this **Library Disk** when linking. Some additional .LIB files are on **LOGITECH Disk 5** if you want to interface *C* language.

Step 3: Prepare a Fully-Linked Compiler diskette for your Modula-2 system.

Insert the *LOGITECH Modula-2* **Fully-Linked Compiler (Disk #3)** into drive **B**, and an empty, formatted disk into drive **A**. Type,

```
COPY B:*.*          A:    ↵
```

You will use this disk to compile *LOGITECH Modula-2* programs. This version of the Compiler requires 512 KBytes of internal (RAM) memory.

Step 4: Prepare an Overlay Compiler diskette for your Modula-2 system.

Insert the *LOGITECH Modula-2* **Overlay Compiler (Disk #4)** into drive **B**, and an empty, formatted disk into drive **A**. Type,

```
COPY B:*.*          A:    ↵
```

You will use this disk to compile larger *LOGITECH Modula-2* programs. This version of the Compiler requires 290 KBytes of internal (RAM) memory.

Step 5: Prepare a Post-Mortem Debugger diskette for your Modula-2 system.

Insert the *LOGITECH Modula-2* **Post-Mortem Debugger (Disk #5)** into drive **B**, and an empty, formatted disk into drive **A**. Type,

```
COPY B:*.REF                A:    ↵
COPY B:*.CFG                A:    ↵
COPY B:*.EXE                A:    ↵
```

This disk will help you debug crashed *LOGITECH Modula-2* programs.

Step 6: Prepare a Working diskette for your Modula-2 system.

Insert the *LOGITECH Modula-2 POINT Editor* **(Disk #1)** into drive **B**, and an empty, formatted disk (which will become your Working diskette) into drive **A**. To copy all the files with the .SYM extension from **Disk 2** onto your Working diskette, type,

```
COPY B:*.SYM        A:    ↵
```

You will use this disk to hold .MOD and .DEF files to be compiled and linked.

PATH and Environment Variables

For *LOGITECH Modula-2* to work properly with a floppy diskette system, you need some additional *DOS* commands in your AUTOEXEC.BAT file, which must be in the root directory of your boot disk. If you do not yet have such a file, create it in the root directory, using your text editor.

These commands assume that you have your *Modula-2* **Working Diskette in drive A**, and a compiler, linker, debugger, or utilities diskette in **drive B**. Append these to your current AUTOEXEC.BAT file, or create an AUTOEXEC.BAT which includes the following commands:

```
SET M2SYM=A:\;
SET M2OBJ=A:\;B:\;
SET M2LIB=A:\;B:\;
SET M2REF=A:\;B:\;
SET M2MOD=A:\;B:\;
SET M2MAP=A:\;B:\;
```

These set the environment for *LOGITECH Modula-2* in a dual floppy configuration. They let your *LOGITECH Modula-2* system take full advantage of *DOS*. More on the environment variables used by *LOGITECH Modula-2* can be found in the section of this manual on the library search strategy.

You must also set the *DOS* environment **PATH** statement (refer to your *DOS* Manual). *DOS* uses this statement *DOS* to search for .EXE files. If your **Modula-2 Working diskette** is in drive **A** and the compiler/linker/debuggers/utilities disk in **drive B**, the environment variable **PATH** should contain the following string:

```
PATH=A:\;B:\;
```

NOTE

Before you use *LOGITECH Modula-2*, be sure to re-start your system so the AUTOEXEC.BAT commands can take effect.

Running on Floppy Diskettes

When you work with ***LOGITECH Modula-2*** on floppy diskettes, use **drive** A for your ***Modula-2 Working diskette.*** It should contain these files:

- .SYM files from the ***LOGITECH Modula-2 Standard Library.***
- .MOD and .DEF files for ***Modula-2*** source text you have created.
- Other files you may create with ***LOGITECH Modula-2***, to use for compiling, linking or debugging.

While you are developing your programs, **drive B** holds a disk for what you are doing. This disk must include the appropriate ***LOGITECH Modula-2*** system files:

To Edit a source file
Insert a working copy of the ***POINT Editor*** disk in **drive B.**

To Compile a source file
Depending on the amount of memory in your machine,
insert a working copy of one of the compiler disks in **drive B.**

To Link a .OBJ file
Insert a working copy of the Library disk in **drive B;**
Insert a working copy of the ***LOGITECH Linker*** in **drive** A; or
Insert a working copy of the ***DOS*** Linker in **drive A.**

To Run a Debugger
Insert a working copy of one of the ***LOGITECH Debugger*** disks in **drive B.**

To Run Utilities
Insert a working copy of ***a LOGITECH*** utility disk in **drive B.**

NOTE

Depending on the capacity of your disks, you can include two or more of the disks mentioned above onto one disk.

If you are using high density diskettes, study the following section on hard disk systems, on the environment variables used by ***LOGITECH Modula-2***, and also study the section on library search strategy.

LOGITECH Modula-2 on a Hard Disk

The most convenient way to use *LOGITECH Modula-2* is with a hard disk. This section tells you two ways to copy files from the distribution disks to your hard disk.

You can copy all the files into the same directory where you write your *LOGITECH Modula-2* programs. However, it's better to take advantage of the structured directory system in *DOS*. This reduces the number of files in your directories and, at the same time, lets you use *LOGITECH Modula-2* from any directory.

You can also install the *LOGITECH System* to a directory of your choice.

Just make sure that you are on the hard disk where you want to keep your *Modula-2* files, and that **Disk #1** is in **Drive A.**

Step 1: Create a Development Environment Directory.

To install *LOGITECH Modula-2* in a directory of your choice, type,

```
MD \YOUR_DIR        ↵
```

Step 2: Run the Install Program

Insert **Disk #1** in **Drive A.**

a) To install the *LOGITECH Modula-2* files *in your root directory*, type

```
A:INSTALL    \     ↵
```

b) To install *LOGITECH Modula-2* in a directory of your choice, type,

```
A:INSTALL    \YOUR_DIR   ↵
```

The INSTALL program then tells you which disks to insert.

Step 3: Add Configuration Statements.

After you install the ***LOGITECH Modula-2 Development System***, you are prompted to add some additional statements to your CONFIG.SYS and AUTOEXEC.BAT files.

An additional line in your CONFIG.SYS file can correct this:

```
SHELL=COMMAND.COM/P/E:n
```

If you are using *DOS 3.1* or *DOS 3.2*, add one of these lines:

- For *DOS 3.1*, *n* is the ***number of 16 byte paragraphs*** allocated for environment space. We recommend that you add this line:

  ```
  SHELL=COMMAND.COM/P/E:31
  ```

- For *DOS 3.2*, *n* is the ***number of bytes*** allocated for environment space. We recommend this line:

  ```
  SHELL=COMMAND.COM/P/E:500
  ```

After you add these statements, restart your system for them to take effect when you work on your *Modula-2* programs.

NOTE

INSTALL.BAT copies your AUTOEXEC.BAT and CONFIG.SYS files to AUTOEXEC.OLD and CONFIG.OLD, and then adds various statements to your AUTOEXEC.BAT and CONFIG.SYS files.

If you need to use the previous settings, simply rename these files with their original extensions.

If you do this, you may also want to save your *Modula-2* AUTOEXEC.BAT and CONFIG.SYS files, too — under names you can use to reinstall your *LOGITECH Modula-2* system, as needed.

The following procedure copies files from *LOGITECH Modula-2* diskettes to a subdirectory you have chosen.

If your system has special constraints, such as directory names that conflict with those used by *LOGITECH Modula-2*, you can install environment step-by-step. You can, of course, copy these files to any directory you choose, as long as you specify their **PATH** in your AUTOEXEC.BAT file.

Perform these *DOS* commands:

Step 1: Create a directory for your development environment.

To install *LOGITECH Modula-2* files in a directory of your choice, use the **MKDIR** (**MD**) command to create that directory.

Step 2: Create subdirectories for LOGITECH Modula-2.

From the system prompt in your chosen subdirectory (e.g., **\YOUR_DIR**), perform these *DOS* commands:

DOS Command		**What it does**
MKDIR M2EXE	↵	Creates the **\YOUR_DIR\M2EXE** directory.
MKDIR M2LIB	↵	Creates the **\YOUR_DIR\M2LIB** directory.
MKDIR M2TMP	↵	Creates the **\YOUR_DIR\M2TMP** directory.
CD M2LIB	↵	Goes to the **\YOUR_DIR\M2LIB** directory
MKDIR DEF	↵	Creates the **\YOUR_DIR\M2LIB\DEF** directory.
MKDIR LIB	↵	Creates the **\YOUR_DIR\M2LIB\LIB** directory.
MKDIR MAP	↵	Creates the **\YOUR_DIR\M2LIB\MAP** directory.
MKDIR MOD	↵	Creates the **\YOUR_DIR\M2LIB\MOD** directory.
MKDIR OBJ	↵	Creates the **\YOUR_DIR\M2LIB\OBJ** directory.
MKDIR REF	↵	Creates the **\YOUR_DIR\M2LIB\REF** directory.
MKDIR SYM	↵	Creates the **\YOUR_DIR\M2LIB\SYM** directory.
CD . .	↵	Return to **\YOUR_DIR** subdirectory

Step 3: Copy the POINT Editor Files.

Insert **Disk #1** with the ***POINT Editor*** into **drive** A and type:

```
COPY A:PT*.*          M2EXE       ↵
COPY A:M2ASSIST.*     M2EXE       ↵
COPY A:CHECKER.*      M2EXE       ↵
COPY A:*.SYM          M2LIB\SYM   ↵
```

This copies files on **Disk #1** to the appropriate directories under **\YOUR_DIR**.

Step 4: Copy the Library Files.

Insert **Disk #2** with the ***Standard Library*** files into **drive** A and type:

```
COPY A:*.LIB          M2LIB\LIB   ↵
COPY A:*.OBJ          M2LIB\OBJ   ↵
```

This copies **.LIB** files from **Disk #2** to **\YOUR_DIR\M2LIB\LIB**, and **.OBJ** files to **\YOUR_DIR\M2LIB\OBJ**.

Step 5: Copy the Fully Linked Compiler Files.

Insert **Disk #3** with the ***Fully Linked Compiler*** into **drive** A and type:

```
COPY A:*.*            M2EXE       ↵
```

This copies the **Fully Linked Compiler** and other files from **Disk #3** to **\YOUR_DIR\M2EXE.**

Step 6: Copy the Overlay Compiler Files.

Insert **Disk #4** with the ***Overlay Compiler*** into **drive** A and type:

```
COPY A:*.*            M2EXE       ↵
```

This copies the ***Overlay Compiler*** files from **Disk #4** to **\YOUR_DIR\M2EXE.**

Step 7: Copy the Post-Mortem Debugger Files.

Insert **Disk #5** with the ***Post-Mortem Debugger*** files into **drive** A and type:

```
COPY A:*.LIB          M2LIB\LIB   ↵
COPY A:*.REF          M2LIB\REF   ↵
COPY A:*.CFG          M2EXE       ↵
COPY A:*.EXE          M2EXE       ↵
```

This copies ***Post-Mortem Debugger*** files from **Disk #5** to **\YOUR_DIR\M2EXE.**

Step 8: Adjust your PATH statement.

Read the next section carefully.

PATH and Environment Variables

For *LOGITECH Modula-2* to work properly with a hard disk system, you need some additional *DOS* commands in your AUTOEXEC.BAT file. AUTOEXEC.BAT executes various commands automatically every time you start your system. If you don't yet have this file, create it with your *POINT* editor in the root directory.

SET Statements

Append the following to your AUTOEXEC.BAT file:

```
SET M2SYM=C:\M2LIB\SYM;
SET M2OBJ=C:\M2LIB\OBJ;
SET M2REF=C:\M2LIB\REF;
SET M2MOD=C:\M2LIB\MOD;
SET M2LIB=C:\M2LIB\LIB;
SET M2MAP=C:\M2LIB\MAP;
SET M2TMP=C:\M2TMP;
```

These settings are correct for a set of *LOGITECH Modula-2* directories created at the root of your hard disk. However, if you create your directories *from a subdirectory*, you must *add that subdirectory name* to the **PATH** statement as well as to the **SET** statements shown above. If your *LOGITECH Modula-2* environment is attached to the "YOUR_DIR" subdirectory, for example, then you must preface your **SET** specification accordingly, as in:

```
SET M2SYM=C:\YOUR_DIR\M2LIB\SYM;
```

etc., for each **SET** specification.

Note: The fictitious directory name **\YOUR_DIR** has been added to the statement in this example.

NOTE

These statements set up the environment variables for ***LOGITECH Modula-2***, and let the ***LOGITECH Modula-2*** system take full advantage of your hard disk. More information on the environment variables used by ***LOGITECH Modula-2*** are found in this manual in **Section 9.1, Library Search Methods**.

The PATH Statement

You must also set the ***DOS*** environment statement **PATH** (refer to your ***DOS Manual***). **PATH** is used by ***DOS*** to search for .EXE files. For example, if you keep .EXE files in **drive C** in a directory named COMMANDS, the PATH statement PATH will read:

```
PATH=C:\COMMANDS;
```

After you use the INSTALL program to add the M2EXE directory it should read:

```
PATH=C:\COMMANDS;C:\M2EXE;
```

Remember

Before using ***LOGITECH Modula-2***, be sure to re-start, re-boot, your system, so the commands of the AUTOEXEC.BAT file will be executed.

Special Notes

A Word About the POINT Editor

The *POINT Editor* has provided the **LOGITECH Modula-2 Development Group** with its editing environment of choice. Apart from the installation instructions you have just read, the *POINT Editor* can also be placed in its own directory. In this way, you can keep just the PT.INI file of your choice in your working directory. For more information see the *POINT User's Manual.*

The *POINT* diskette includes a file named PTM2.INI which can be copied into PT.INI, the Initialization file for the *POINT Editor.*

A Word About the MOD Editor

If you are more accustomed to the *MOD Editor* from previous releases, we have included a file named PTMOD.INI. You can copy this file to PT.INI on your POINT working disk or directory, for the accustomed *MOD* interface with the additional features of *LOGITECH Modula-2, Version 3.0.*

A Word About Mice

We recommend either the *LOGITECH Bus Mouse* or the *LOGITECH C7 Mouse* for editing source text files and for running either the *LOGITECH Symbolic Post-Mortem Debugger* or the *LOGITECH Symbolic Run-Time Debugger.* We know you will find either *LOGITECH Mouse* an ideal tool for the *LOGITECH Modula-2 Development System*, as well as for other editing and graphics tasks.

Be sure to load your mouse driver software before you atttempt to edit or debug your *Modula-2* work. Instructions for installing mouse software is in your mouse manual.

Chapter 1
A Tutorial

The best way to learn a new language is to use it. The same is true for programming languages.

In this chapter you will enter and run a simple *Modula-2* program. It's like getting acquainted with a city by looking at a map and a tour book: it can get you started. If you want adventures, you will then know just enough to get into trouble and also just enough to figure your way out of trouble.

This tutorial uses the ***POINT Editor*** with the `M2ASSIST` extension menu, which provides a fast, flexible development environment, whether you are a beginner or an experienced programmer. ***POINT*** is easy to learn, easy to use, and is the ***LOGITECH Modula-2*** development environment of choice.

The best environment will also include a ***LOGITECH Mouse***, since the ***POINT Editor*** optimizes the three button standard provided by ***LOGITECH.*** If you do not yet have a mouse, or are operating temporarily on a non-mouse system, the ***POINT Manual*** has a special summary for mouse emulation with *POINT* on a standard keyboard.

NOTE

Before you begin this tutorial, be sure you have backed up your ***LOGITECH Modula-2*** diskettes and installed the system, and that the PATH and SET statements are written as described in the preceding <u>Installation</u> section.

Task 1: Get Ready

This tutorial assumes that you have used the default installation described in the Installation section, above. If you are already using a directory with this name for other purposes, choose another directory name, and adjust the following instructions accordingly.

Step 1: Move to Your Development Directory.

From wherever you are, on the command line, type

```
CD\YOUR_DIR ↵
```

where **\YOUR_DIR** is the path and directory you have specified in the Installation.

Step 2: Move to the M2TMP directory.

Type

```
CD M2TMP ↵
```

This takes you to the **\YOUR_DIR\M2TMP** directory

For this tutorial we will work from the M2TMP sub-directory. Be sure that your ***POINT*** files are in a directory that is listed in your **PATH** statement. Refer to the Installation section, in the front of this manual.

Step 3: Bring the PTDEMO.MOD file into the M2TMP sub-directory.

Use the *DOS* **COPY** command, or a file management utility to copy this file into the **YOUR_DIR\M2TMP** directory.

NOTE

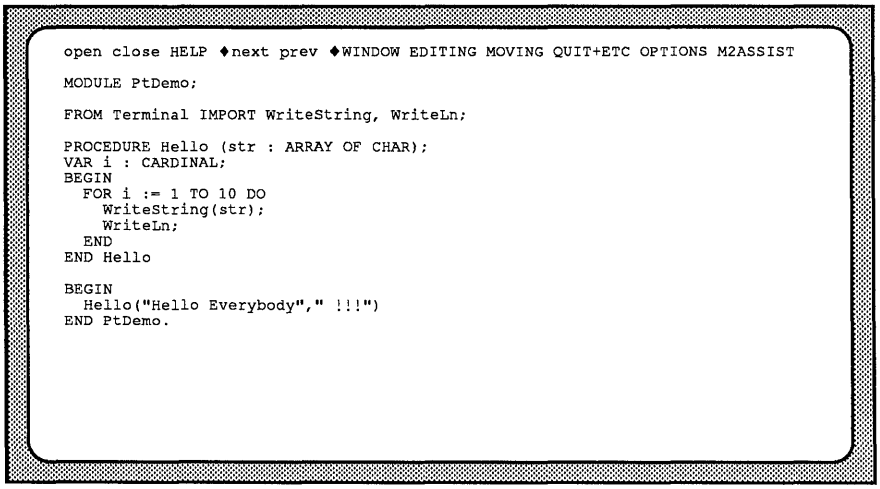
Using **\M2TMP** to create your ***Modula-2*** programs is a suggestion and not a requirement of ***LOGITECH Modula-2***. You can just as easily create and/or use any other directory.

Task 2: Bring up the PTDEMO.MOD File

Again, you can create *Modula-2* files with any general purpose text editor. However, to run the syntax checker you must be in the *POINT* environment. To load *POINT*, type

PT PTDEMO.MOD ↵

Here is the *POINT* screen you will see, with a listing for PTDEMO.MOD as it appears in a window in the *POINT* environment.



```
open close HELP ♦next prev ♦WINDOW EDITING MOVING QUIT+ETC OPTIONS M2ASSIST

MODULE PtDemo;

FROM Terminal IMPORT WriteString, WriteLn;

PROCEDURE Hello (str : ARRAY OF CHAR);
VAR i : CARDINAL;
BEGIN
  FOR i := 1 TO 10 DO
    WriteString(str);
    WriteLn;
  END
END Hello

BEGIN
  Hello("Hello Everybody"," !!!")
END PtDemo.
```

For more information on *POINT*, see the **Tutorial** in the ***POINT Editor User's Manual.***

Task 3: M2ASSIST — The Syntax Checker

M2ASSIST is composed of several functions, some of which are executed from the `M2ASSIST` menu at the top of the *POINT* screen, and some of which use the [Alt] key in combination with one of the twenty-six alphabetical keys.

The first function we will use is `Check Syntax`, which appears in the `M2ASSIST` menu.

Step 1: Check the Syntax of PTDEMO.MOD.

Press [■ ❑ ❑] on the `M2ASSIST` menu and use the highlight to execute the `Check Syntax`. The syntax checker stops at `BEGIN` of the main program and the following message appears on the status line:

```
';' expected at 'BEGIN'
```

Actually, a semicolon is missing after `END Hello`.

Step 2: Correct the PTDEMO.MOD listing.

Place a semicolon after `Hello`, as in the partial listing below. The corrected listing should read:

```
...
                        WriteLn
                  END
            END Hello;

            BEGIN
...
```

Now run `Check Syntax` again, and you will see the message:

```
Syntax checker: no errors found
```

This means you are ready now to use the *LOGITECH Modula-2 Compiler* which takes PTDEMO.MOD and creates PTDEMO.OBJ.

Task 4: M2ASSIST — The Compiler

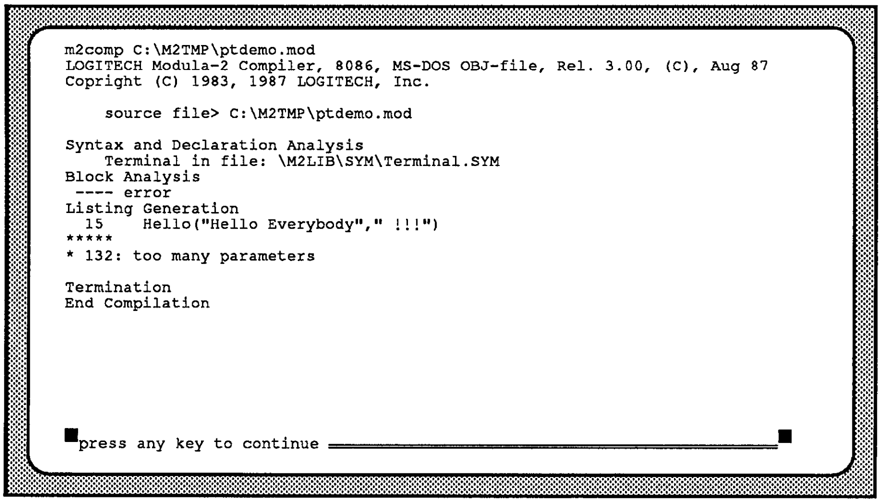
The next task is to attempt to compile PTDEMO.MOD.

When compilation is done, any key returns you to the source file in the editing window.

Step 1: Run the compiler.

Press [■ ❑ ❑] on the **M2ASSIST** menu and drag the cursor down the menu to select **Compile**. A message at the bottom of the screen asks for options. Press [↵] to accept the default options.

The screen is redrawn as follows:



```
m2comp C:\M2TMP\ptdemo.mod
LOGITECH Modula-2 Compiler, 8086, MS-DOS OBJ-file, Rel. 3.00, (C), Aug 87
Copright (C) 1983, 1987 LOGITECH, Inc.

    source file> C:\M2TMP\ptdemo.mod

Syntax and Declaration Analysis
    Terminal in file: \M2LIB\SYM\Terminal.SYM
Block Analysis
 ---- error
Listing Generation
  15    Hello("Hello Everybody"," !!!")
*****
* 132: too many parameters

Termination
End Compilation




■press any key to continue ═══════════════════════════════════════════════■
```

Step 2: Return to the editing session.

Press any key to return to the editing session. You will see the listing file you left when you selected the **Compile** command. In addition, at the bottom of the screen, you will see a message that reads:

1 COMPILE ERROR.

Task 5: M2ASSIST — Find Next Error

Errors found during Compilation can be found quickly in your source code with **Find Next Error**. **Find Next Error** highlights the next statement tagged with a compilation error after invoking Compile or Syntax checking.

You can insert/delete lines of text in the file and then go to the next tagged error.

Corresponding error messages from the .LST file are shown in a temporary window. The error window closes at the first action.

Step 1: Look for the error.

Press [■ ❑ ❑] on the **M2ASSIST** menu and drag the cursor down the menu to select **Find Next Error.**

The screen shifts to the general area of the error which is highlighted, and a box appears at the bottom of the screen with the following message:

```
  15    Hello("Hello Everybody","!!!")
*****                                ^132
* 132: too many parameters
```

Step 2: Correct the source code.

Move to the area in the source code that is highlighted. As soon as you press a key or move to the highlighted text the box with the error message dissappears, leaving the highlighted text.

The source of the error is two string parameters where only one is allowed. Remove the error (",") between **Everybody** and **!!!** in the line **Hello("Hello Everybody","!!!").**

The corrected line will read:

```
Hello("Hello Everybody!!!")
```

Step 3: Look for the next error.

Again, press [■ □ □] on the **M2ASSIST** menu and drag the cursor down the menu to select **Find Next Error**.

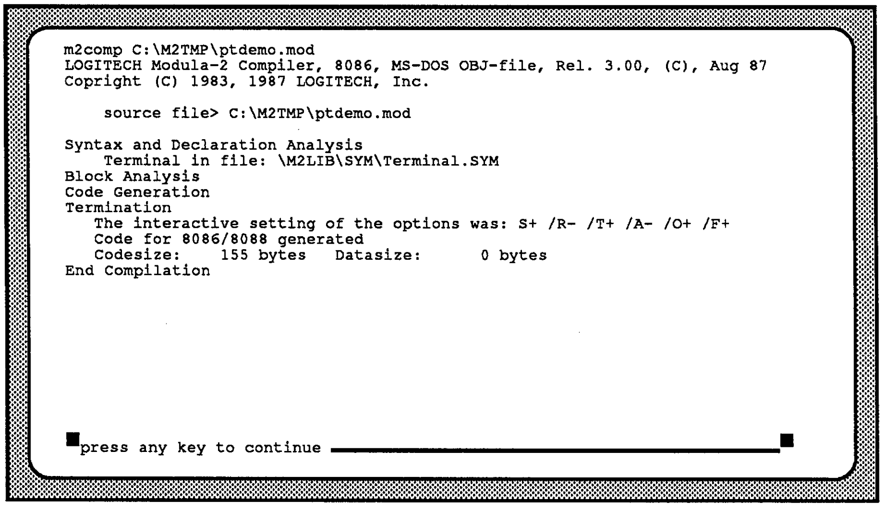
That was apparently the only error, since the message on the status line at the bottom of the screen reads:

```
NO MORE ERRORS
```

Step 4: Compile the source code again.

Now press [■ □ □] on the **M2ASSIST** menu and drag the cursor down the menu to again select **Compile**.

The screen you get looks like the following:



```
m2comp C:\M2TMP\ptdemo.mod
LOGITECH Modula-2 Compiler, 8086, MS-DOS OBJ-file, Rel. 3.00, (C), Aug 87
Copright (C) 1983, 1987 LOGITECH, Inc.

    source file> C:\M2TMP\ptdemo.mod

Syntax and Declaration Analysis
    Terminal in file: \M2LIB\SYM\Terminal.SYM
Block Analysis
Code Generation
Termination
   The interactive setting of the options was: S+ /R- /T+ /A- /O+ /F+
   Code for 8086/8088 generated
   Codesize:    155 bytes   Datasize:      0 bytes
End Compilation



■press any key to continue ___________________________________________■
```

Step 5: Return to the POINT Window.

As soon as you press a key to return to your source code in the *POINT* window, you find the following message at the bottom of the screen.

```
no listing file was produced during the compile.
```

Task 6: M2ASSIST — The Linker

When PTDEMO.MOD is successfully compiled, an additional file named PTDEMO.OBJ is created by the compiler.

A Linker uses PTDEMO.OBJ to generate PTDEMO.EXE.

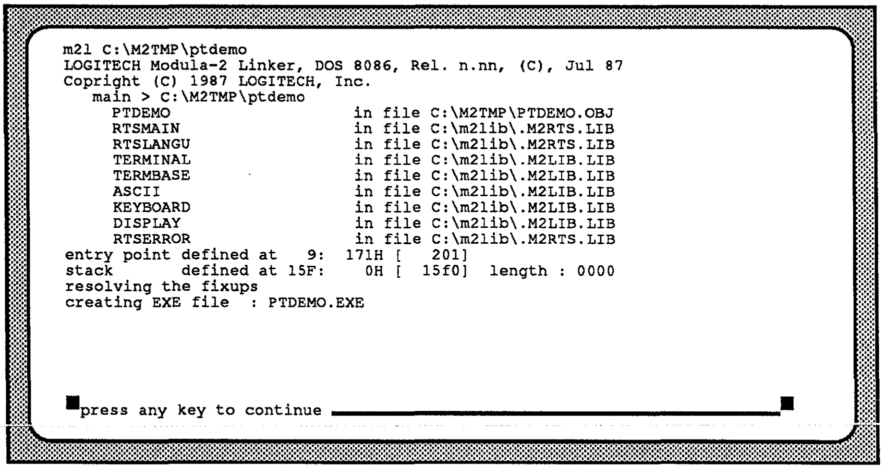
There are two ways to link an .OBJ file: use the `M2ASSIST` menu with the *LOGITECH Linker*; or choose `Exit to DOS Shell` from the `QUIT&ETC` menu, and use a *DOS* or other linker. If you use other than the *LOGITECH Linker*, include the directory with your linker in the **PATH** statement, as mentioned in Installation.

Link with the LOGITECH Linker

Step 1: Link the .OBJ file.

Press [■ ❑ ❑] on the `M2ASSIST` menu and drag the cursor down the menu to select `Link`. Press [↵] to accept the default Linker options.

The screen is redrawn as follows:



```
m21 C:\M2TMP\ptdemo
LOGITECH Modula-2 Linker, DOS 8086, Rel. n.nn, (C), Jul 87
Copright (C) 1987 LOGITECH, Inc.
   main > C:\M2TMP\ptdemo
     PTDEMO                    in file C:\M2TMP\PTDEMO.OBJ
     RTSMAIN                   in file C:\m2lib\.M2RTS.LIB
     RTSLANGU                  in file C:\m2lib\.M2RTS.LIB
     TERMINAL                  in file C:\m2lib\.M2LIB.LIB
     TERMBASE                  in file C:\m2lib\.M2LIB.LIB
     ASCII                     in file C:\m2lib\.M2LIB.LIB
     KEYBOARD                  in file C:\m2lib\.M2LIB.LIB
     DISPLAY                   in file C:\m2lib\.M2LIB.LIB
     RTSERROR                  in file C:\m2lib\.M2RTS.LIB
entry point defined at    9:  171H [   201]
stack       defined at 15F:     0H [  15f0]  length : 0000
resolving the fixups
creating EXE file   : PTDEMO.EXE



■press any key to continue ______________________________________■
```

You are now ready to run the *PTDEMO* program you just linked with the *LOGITECH Linker.*

Link with the DOS Linker

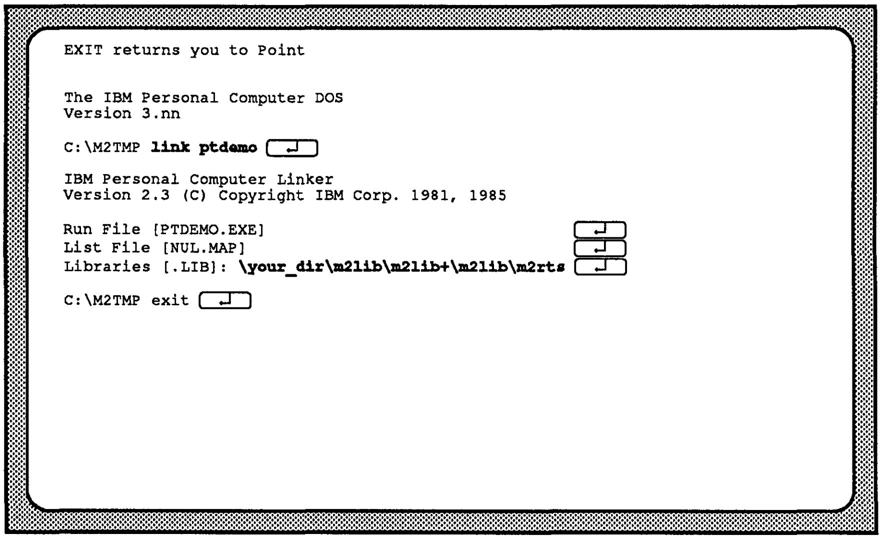
If you have not yet purchased the *LOGITECH Modula-2 Toolkit*, use the linker that came with your copy of *DOS*.

Step 1 Select a DOS Shell.

Press [■ □ □] on the `QUIT+ETC` menu and drag the cursor down the menu to select **`Execute DOS Shell`**.

Step 2 Link from DOS

The screen below shows the prompts you will see as you link your copy of `PTDEMO.OBJ`. Information to be entered is in **`bold face`**, and finalized with [↵], unless there is no response to be entered in which case press [↵] to signify the default response.



```
EXIT returns you to Point

The IBM Personal Computer DOS
Version 3.nn

C:\M2TMP link ptdemo [↵]

IBM Personal Computer Linker
Version 2.3 (C) Copyright IBM Corp. 1981, 1985

Run File [PTDEMO.EXE]                                         [↵]
List File [NUL.MAP]                                           [↵]
Libraries [.LIB]: \your_dir\m2lib\m2lib+\m2lib\m2rts [↵]

C:\M2TMP exit [↵]
```

Enter the library names at the **`Libraries [.LIB]:`** prompt, as shown above:

\YOUR_DIR\M2LIB\M2LIB+\M2LIB\M2RTS [↵].

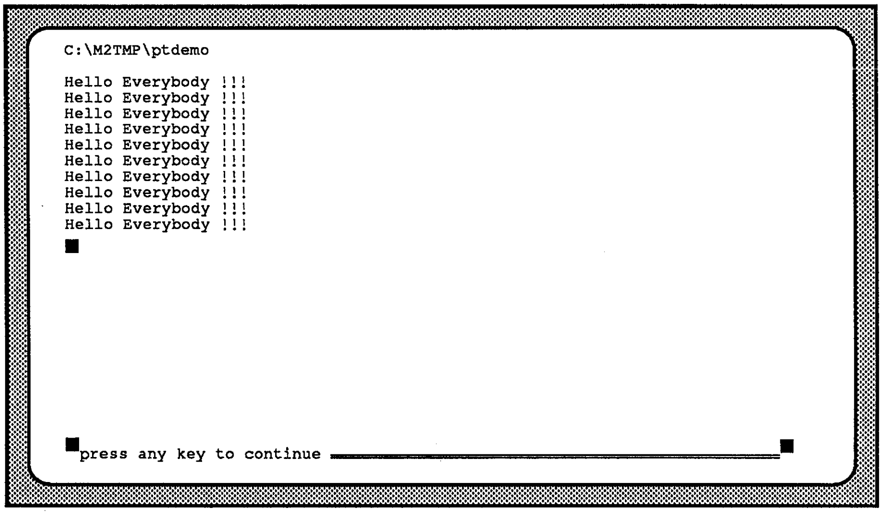
Step 3: Return to the POINT Window.

At the final prompt, type **EXIT** [↵], to return to the *POINT* window. Now you can run the PTDEMO program you just linked with the *DOS Linker*.

Task 7: M2ASSIST — Run .EXE File

Step 1: Run the .EXE file.

Press [■ ☐ ☐] on the **M2ASSIST** menu and drag the cursor down the menu to select **Run**. The screen is redrawn as follows:

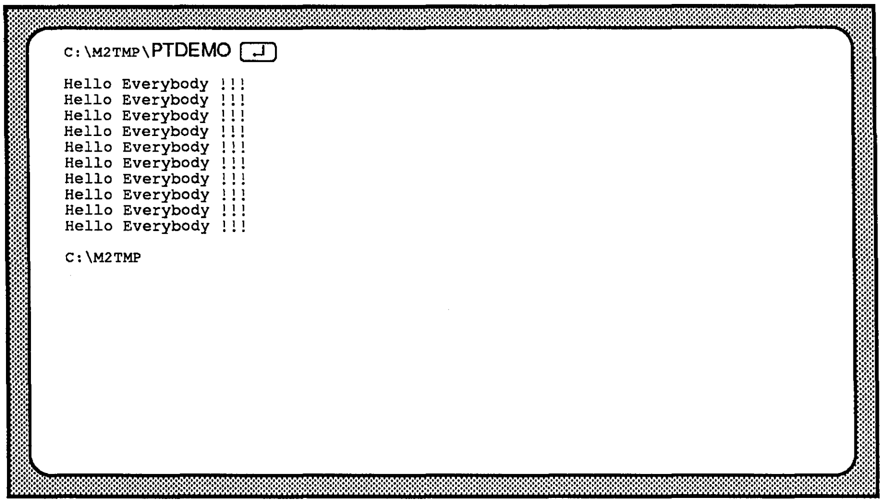


```
C:\M2TMP\ptdemo

Hello Everybody !!!
Hello Everybody !!!
Hello Everybody !!!
Hello Everybody !!!
Hello Everybody !!!
Hello Everybody !!!
Hello Everybody !!!
Hello Everybody !!!
Hello Everybody !!!
Hello Everybody !!!
■
```

```
■press any key to continue ══════════════════════════════════■
```

Step 2: Run the .EXE file from DOS.

Quit *POINT* and return to *DOS*, by pressing Alt-Q. Now, from the command line, type **PTDEMO** ↵. The screen is redrawn as follows:



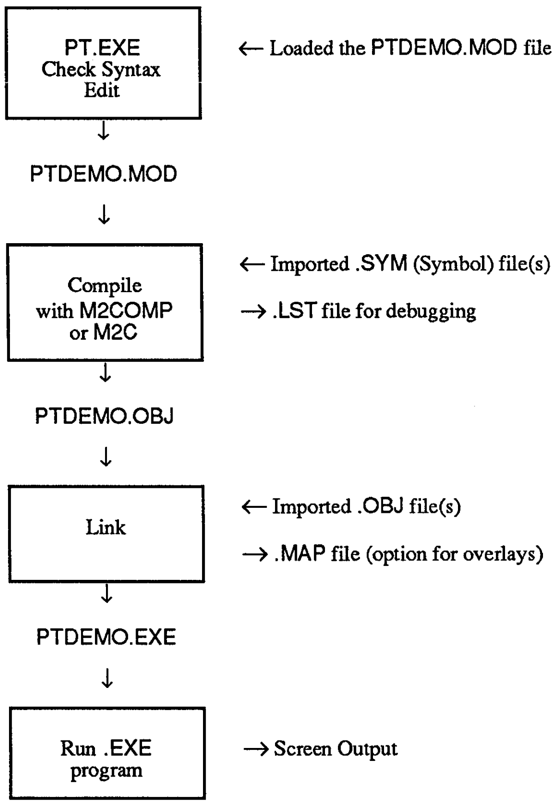
```
C:\M2TMP\PTDEMO ↵

Hello Everybody !!!
Hello Everybody !!!
Hello Everybody !!!
Hello Everybody !!!
Hello Everybody !!!
Hello Everybody !!!
Hello Everybody !!!
Hello Everybody !!!
Hello Everybody !!!
Hello Everybody !!!

C:\M2TMP
```

NOTE

For information on other useful features of *POINT*, including multiple-window editing, and additional features of the **M2ASSIST** extension. consult the *POINT Editor User's Manual.*

Review: The POINT Entry/Run Cycle

You started by invoking the *POINT* Editor, with PTDEMO.MOD loaded as an argument. Then, from within *POINT* you were able to check syntax, compile, link, and run the program. Let's look at the tools you just used and the steps you just took:



Now its time for you to write some ***Modula-2*** programs of your own. Refer to the bibliography in <u>**Appendix A**</u> which lists books, magazines, and user groups that are devoted to ***Modula-2***. And remember the words of Leonardo DaVinci:

"The greatest tragedy in life is for theory to outstrip practice."

Good luck in your study of this great new programming language!

Chapter 2
Modula-2 for the Pascal Programmer

Since ***Modula-2*** evolved from ***Pascal*** it's easy for ***Pascal*** programmers to become familiar with ***Modula-2***.

There are two levels of difference between ***Modula-2*** and ***Pascal.*** First, ***Modula-2*** implements modern software engineering, such as, data abstraction, functional abstraction, concurrency and more frequent use of modular programs. All these features are not part of the standard ***Pascal*** definition, neither are they present in any implementation. The second level of difference consists of relatively minor changes in ***Modula-2*** program syntax and constructs.

The most important difference is the introduction of the module.

2.1 Types of Modules

Modula-2 has three types of modules: program, definition, and implementation modules. Program modules contain the source code for your main program. Program libraries are created from matched pairs of definition modules and implementation modules. Source code for all modules types is stored as standard text files and may be modified by any text editor capable of working with these files. Program and implementation modules use the extension .MOD. Definition modules use the file extension .DEF.

2.1.1 Program Modules

A program module is the main module of your program. A program consists of all the modules that are referred to directly or indirectly by the main module. For program modules, the module code, which is declared following the last BEGIN, constitutes the main program. After initialization of all imported modules, the program will start there.

The examples in the following section are program modules. Program modules have the following form:

```
MODULE <modulename>;
   Import from the library modules to use, if any, in the form:
      FROM <modulename> IMPORT
         <list of identifiers separated by commas>;
      or:
      IMPORT <modulename>;
      Declaration of constants, types, variables and procedures.
   BEGIN
      Code of the main program.
   END <modulename>.
```

The list of identifiers imported may contain the names of constants, types, variables and procedures exported from a library module. These names must be separated by commas. Refer to Wirth's book ***Programming in Modula-2*** for a more detailed explanation of the module syntax.

2.1.2 Definition Modules

Definition modules define the interface between modules. By separating the definition of the interface between modules from the implementation of those modules, the implementations may be modified without having to recompile the entire system. As programmers involved with large systems know, recompiling the entire system can be a very time consuming process.

Definition modules have the following form:

```
   DEFINITION MODULE <modulename>;
      Import from the library modules to use, if any, in the form:
      FROM <modulename>IMPORT
         <list of names separated by commas>;
      or:
      IMPORT <modulename>;
      EXPORT QUALIFIED
         <list of names separated by commas>;
      Declaration of constants, types, variables and procedures.
      Procedure declarations consist of the procedure header only,
         including the parameter list.
   END <modulename>.
```

2.1.3 Implementation Modules

Implementation modules contain the statements required to perform the functions defined in the definition modules. They are similar in format to program modules except their module body does not need to constitute a main program. Libraries are constructed from matching sets of definition and implementation modules.

Implementation modules have the following form:

```
 IMPLEMENTATION MODULE <modulename>;
Import from the library modules to use, if any, in the form:
    FROM <modulename> IMPORT <list of names separated by commas>;
    or:
    IMPORT <modulename>;
    Declaration of constants, types, variables and procedures.
    Procedure declarations consist of the header and body,
    including the code of the procedure.
 BEGIN
    Module initialization code.
 END <modulename>.
```

The constants, types and variables declared in the corresponding definition module, must not be repeated in the implementation. These names are known implicitly. However, for every procedure specified in the definition part, a complete procedure, with matching name and parameter list, must be contained in the implementation part.

Modula-2 enhances software production by shortening development time. While the real speed of a ***Pascal*** or ***Modula-2*** compiler is important, consider the time involved in software production cycle. Include time for software updates and alterations. ***Pascal*** often translates this into a significant additional programming effort, which offsets the benefit of short ***Pascal*** compile time. ***Modula-2*** minimizes this wasteful "domino effect" by using highly independent module libraries.

The ***Modula-2*** core is smaller than the ***Pascal*** core, because ***Modula-2*** has no predefined I/O statements, math functions or string manipulation routines. ***Modula-2*** imports them from library modules. So, ***Modula-2*** really practices what it preaches!

This chapter has two main sections. The first shows a ***Pascal*** programmer how to write a ***Modula-2*** program or to convert a ***Pascal*** program to ***Modula-2***. The second explains the concept of the module.

The next section discusses differences in syntax and construct between ***Pascal*** and ***Modula-2***. This should allow a programmer to convert ***Pascal*** programs or to write new ones in ***Modula-2***.

2.2 First Steps From Pascal To Modula-2

To demonstrate some basic syntax differences between ***Pascal*** and ***Modula-2***, consider the following simple number-squaring program:

```
MODULE FirstDemo;

(* List of imported procedures *)
FROM InOut IMPORT WriteString, WriteInt, ReadInt, WriteLn;

VAR Number, Square : INTEGER; (* Programs' identifiers   *)

BEGIN
   (* ---------- Input -------*)
   WriteString("Type an integer "); ReadInt(Number);
   (* ------ Processing ------*)
   Square := Number * Number;
   (* ---------- Output ------*)
   WriteString("Number = "); WriteInt(Number,4); WriteLn;
   WriteString("It's square = "); WriteInt(Square,6);
   WriteLn;
END FirstDemo.
```

The following new concepts specific to ***Modula-2*** are in the previous example:

- ***Modula-2*** programs start with the reserved word **MODULE** followed by a program name. The same name appears after the very last **END** statement. The program name takes no arguments.
- All identifiers are case sensitive in ***Modula-2***. Thus changing the case of one letter in an identifier's name is sufficient to create a new identifier name.
- ***Modula-2*** reserved words are always in upper case letters.
- Comments are enclosed in (* and *). ***Modula-2*** uses curly braces for sets, hence they do not enclose comments as in ***Pascal***. ***Modula-2*** allows nested comments.
- All I/O procedures are imported from a library module, such as **InOut** in this case. Hence, ***Pascal***'s multipurpose **WRITELN** is replaced with a series of output procedures. Each outputs only one item. If you look for the **InOut** module in ***Programming in Modula-2***, by Niklaus Wirth, you will find that it exports many procedures. In our example we chose to "import" the four required procedures only.

2.3 More Differences

Labels and GOTO statements are no longer supported by *Modula-2*. To translate *Pascal* programs with labels or GOTO statements, you need to rewrite your *Pascal* program.

Constants are declared, similar to *Pascal*. *Modula-2* allows for constant expressions to be used wherever a constant is expected. Integer constants now include hexadecimal and octal numbers. Thus: 12AFH represents a hexadecimal number, ending with an H. 27B is an octal number, ending with a B. In addition, 27C represents the same octal number, but its type is CHAR. Real constants are similar to those in *Pascal*. When expressed in scientific notation, only the uppercase E must be used. All real constants require a decimal point.

Character and string constants are similar to *Pascal* with an enhancement. Single or double quotes may be used to delimit them. Thus, `"Hello"` and `'Hello'` are both acceptable, but `"Hello'` is not. The choice of delimiter may be dictated by the presence of a quote symbol as part of the string constant. Thus `"Don't"` forces the use of double quotes, since a single one is part of the string.

Similarly, `'They have "some" children'` must be delimited by single quotes.

Modula-2 defines these basic data types: integer, boolean, characters, real, cardinal and bitset. The first three types are used as they are in *Pascal*. Using reals has a restriction that prevents it from being mixed with integers and cardinals in an expression. Predefined type converter functions must be used. Cardinals are unsigned integers with values ranging from zero to an upper, machine-fixed limit. While cardinals and integers are assignment compatible, they too cannot be directly mixed in an expression. The bitset type is a predeclared set type for low level data manipulation.

Modula-2 supports sets with some syntax modifications. Set constants are enclosed in curly braces. Set types are defined with SET OF <enumerated or subrange types>:

- `CONST OctalNumSet = {1,2,3,4,5,6,7,8};`
- `TYPE Binary = SET OF [0..1];`

Modula-2 implements a generous number of set operations, including the symmetric set differences.

Modula-2 supports enumerated types just like ***Pascal***. Subranges are also similar, but ***Modula-2*** requires them to be enclosed in square brackets. Why? This enables subrange types to be used in defining array limits, as in:

```
TYPE SmallRange  = [1..10];
   BigRange      = [1..100];
   SmallArray    = ARRAY SmallRange OF REAL;
   BigArray      = ARRAY BigRange OF REAL;
   HugeArray     = ARRAY SmallRange, BigRange OF REAL;
   Table         = ARRAY [1..10],[1..100] OF REAL;
   Matrix        = ARRAY [1..10,1..10] OF REAL;  (* WRONG! *)
```

The above list also shows the difference between the two languages in declaring arrays. ***Modula-2*** allows subrange types to be used. Moreover, multidimensional arrays must have the range of each dimension separated by a comma. However, using multidimensional arrays in a program follows the familiar ***Pascal*** notation.

Modula-2 regards character strings as merely an array of characters. In normal practices the ASCII null (zero code) is used as a string terminator. However, it is possible to use slightly more elaborate record structures to implement strings. String manipulation depends on library modules. The standard string library offers the essential operations and treats strings as an array of characters.

Fixed records are no different in ***Modula-2*** than in ***Pascal***. Variant records have been extended to allow for more than one variant field. In addition, the latter may have an **ELSE** clause option. Consider the following example:

```
TYPE Material = (Element, Compound);
     State    = (Liquid, Gas, Solid);

     ChemicalPointer = POINTER TO Chemical;

     Chemical = RECORD
        Name    : ARRAY [1..40] OF CHAR;
        Formula : ARRAY [1..20] OF CHAR;
        CASE MaterialType  : Material OF
             Element       : AtomicNumber     : CARDINAL;
                             Valence          : INTEGER;
                             AtomicWeight     : REAL |
             Compound      : Molecularweight  : REAL;
                             CationCharge,
                               AnionCharge    : INTEGER;
                             CationName,
                               AnionName      : ARRAY [1..15] OF CHAR;
        END;

      CASE NormalPhysicalState:State OF
         Liquid : LiquidDensity,BoilingPoint     : REAL |
         Gas    : VaporPressure,VaporTemp        : REAL |
         Solid  : SpecificGravity, MeltingPoint  : REAL;
      END;
```

Dynamic records can be created and accessed using pointers. Their declaration is a bit more verbose, using the keywords **POINTER TO**, as in:

```
MODULE PointerDemo;
(* Partial listing *)
TYPE    CardPtr    = POINTER TO CARDINAL;
        ComplexPtr = POINTER TO Complex;
        Complex    = RECORD
                          Re, Imag : REAL;
                     END;

   VAR CPtr : ComplexPtr;
         (* Other variables declared here *)
   BEGIN
      New(CPtr); (* Create new dynamic record *)
         (* Initialize to square root of minus one *)
      CPtr^.Re := 0.0; Cptr^.Imag := 1.0;
         (* rest of the program *)
   END PointerDemo.
```

As shown above, pointers are used with the carat symbol. The **WITH** keyword is also used in ***Modula-2*** to reference a record's field name without the record-name-dot notation. A mandatory **END** is required. ***Modula-2*** allows one record identifier per **WITH** statement. There is no need for the **BEGIN** keyword after the **DO** reserved word.

Creating dynamic variables with variant record structures uses the predefined **NEW** procedure and includes variant tags as additional arguments. Recalling the variant record **`Chemical`**, and its related pointer type **`ChemicalPointer`**, we proceed to define the following pointer-typed variables:

```
FROM Storage IMPORT ALLOCATE
VAR Iron, Water, Oxygen : ChemicalPointer;
```

and create dynamic variables using the above pointers:

```
(* Iron is an element and a solid at normal conditions *)
NEW(Iron,Solid) ;

(* Water is a compound and a liquid at normal conditions *)
NEW(Water,Liquid);

(* Oxygen is an element and a gas at normal conditions *)
NEW(Oxygen,Gas);
```

Since I/O operations are no longer in the ***Modula-2*** core, the predefined ***Pascal*** **FILE OF <type>** has no equivalent. Instead, File structures depend on the I/O library module.

Modula-2 variable declaration is identical to that in ***Pascal*** with one additional feature. An absolute address in square brackets, may follow the variable name. For example:

```
VAR Screen[0B800H:0H] : ARRAY [1..MAXCOL],[1..MAXROW] OF CHAR;
```

Modula-2 has simplified the syntax of statement blocks. In ***Pascal*** loops or **WITH** statements, if the **DO** reserved word was followed by **BEGIN**, there is a compound statement. ***Modula-2*** has dropped the **BEGIN** keyword after **DO** and replaced it with a mandatory **END** to close the loop or **WITH** body.

The **IF** statement is very similar to that in ***Pascal*** with the following changes:

- No need for **BEGIN-END** in **THEN** or **ELSE** clauses with more than one statement.
- The **IF** construct must close with the **END** statement.
- The ***Pascal*** **ELSEIF** is now **ELSIF**, one letter shorter.

The above changes in the following function calculate your checking account balance. For less than $500, a local bank charges you with a $5.00 service charge. For under $1500, you get 5.4% interest rate. Beyond that amount, you get a 9.4% rate.

```
PROCEDURE BankOnIt(Savings : REAL) : REAL;

VAR BankCharges, Interest : REAL;

   BEGIN
      BankCharges := 0.0;
      IF Savings < 500. THEN
         (* Apply a five dollar service charge *)
          BankCharges := 5.00;
          Interest := 5.4 (* percent *)
      ELSIF Savings < 1500. THEN
          (* same rate as above, but no charges *)
          Interest := 5.4
      ELSE (* Very nice account *)
          Interest := 9.4;
   END; (* IF statement *)
      RETURN (Savings * (1. + Interest/100.) - BankCharges);
END BankOnIt;
```

The **CASE** statement has also been enhanced in ***Modula-2***. A much needed catch-all **ELSE** clause is recognized. Statement sequences for each case are simply separated by vertical bars. The **BEGIN-END** keywords are no longer needed for compound statements. Here, the **CASE** statement translates numeric school grades into letters:

```
    CASE NumericGrade OF
       90..100 : Grade := 'A';
                 Message := 'Very Nice work champ!' |
       80..89  : Grade := 'B';
                 Message := 'Nice work' |
       70..79  : Grade := 'C';
                 Message := 'OK, but you can do better'
       ELSE      Grade := 'F';
                 Message := 'Sorry, you failed';
     END; (* CASE NumericGrade *)
```

Modula-2 has improved on loops where needed. The **REPEAT-UNTIL** loop is identical to its implementation in ***Pascal***. The **WHILE-DO** loop now requires a mandatory **END** statement to bracket the loop. This is regardless of the number of statements inside the loop. No **BEGIN** keyword is required after the **DO**. The **FOR-DO** loop has undergone even more changes. Like the above **WHILE** loop, it must have an **END** statement. ***Modula-2*** allows the loop counter to increment/decrement by more than one, using the **BY** clause. These "steps" can be positive or negative. Appropriately, ***Modula-2*** no longer supports the ***Pascal*** **DOWNTO** keyword. Here is a short program demonstrating the **FOR-DO** loop in its new construct.

```
MODULE AreaUnderCurve;
  (* Program to calculate area under curve Y = X*X between *)
  (* zero and one.   Simpson's rule is used.               *)
FROM InOut IMPORT WriteString, WriteLn;
FROM RealInOut IMPORT WriteReal;

VAR Y : ARRAY [1..11] OF REAL;
      Increment, Area, SumEven, SumOdd : REAL;
      i                                : CARDINAL

BEGIN
   Increment := 0.1;
           i := 1
   WHILE i <= 11 DO (* Initialize Y array *)
         Y[i] := (Increment * FLOAT(i)) * (Increment * FLOAT(i))
         INC(i) (* Increment i by one *);
   END:
          (* Initialize summations *)
          SumEven := 0.0; SumOdd := 0.0;
          (* Start loop for summing even terms *)
          FOR i   := 2 TO 10 BY 2 DO
          SumEven := Sumeven + Y[i];
          END;
       (* Start loop for summing odd terms, counting back *)
       FOR i := 9 TO 1 BY -2 DO
            SumOdd := SumOdd + Y[i];
       END;
       Area := Increment / 3.0 * (Y[1] + 4.0*SumEven + 2.0*SumOdd + Y[11]);
       WriteString("Area for X^2 between 0 and 1 = ");
       WriteReal(Area,14); WriteLn;
  END AreaUnderCurve.
```

Modula-2 introduces a new loop construct, the open loop. The keywords **LOOP** and **END** define the open loop body. To exit such a loop an **EXIT** statement is used. The open loop is very flexible. An if statement with **EXIT** placed right after the **LOOP** keyword gives the effect of a **WHILE** loop, as in:

```
i := 0; j := 0;              i := 0; j := 0;
WHILE i < 10 DO              LOOP
                             IF i >= 10 THEN EXIT; END;
  INC(i);                       INC(i);
  INC(j,i);                     INC(j,i)  (* j := j + i *);
    END;                     END;
```

Similarly, placing the loop exit test just before the end of the loop simulates the **REPEAT-UNTIL** loop.

```
    i := 0; j := 0           i := 0; j := 0;
    REPEAT                      LOOP
         INC(i);                   INC(i);
         INC(j,i);                 INC(j,i);
                                IF i = 10 THEN EXIT; END;
    UNTIL i = 10;              END;
```

The loop exit test can be anywhere inside the loop body, as shown in the following example. The program calculates the Bessel function of the first kind.

```
MODULE BesselFunction;

FROM InOut IMPORT WriteString, WriteLn, ReadCard;
FROM RealInOut IMPORT WriteReal, ReadReal;

CONST Epsilon = 1.0E-08;

VAR  Sum, Term, X, Y,
   Factor1, Factor2, Factor3, PowerTerm : REAL;
   Order, i                             : CARDINAL;

   BEGIN
      WriteString("Enter order of Bessel function ");
      ReadCard(Order); WriteLn;
      WriteString("Enter argument ");
      ReadReal(X); WriteLn;
      Sum := 0.0; i := 0;
      Y := -0.25 * X * X;
      Factor1 := 1.0; Factor2 := 1.0;
      Factor3 := 1.0; PowerTerm := 1.0;
      IF Order > 0 THEN
         FOR i := 1 TO Order DO
             Factor3   := Factor3 * FLOAT(i);
             PowerTerm := PowerTerm * X / 2.0;
      END;
   END;

   i := 0; (* Initialize counter *)
      LOOP
         Term := Factor1 / Factor2 / Factor3;
         Sum  := Sum + Term;
         (* Is added term insignificant ? *)
         IF ABS(Term) < Epsilon THEN EXIT; END;
         INC(i);
         Factor1 := Factor1 * Y;
         Factor2 := Factor2 * FLOAT(i);
         Factor3 := Factor3 * FLOAT(i);
      END;
   (* Program flow resumes here after EXIT *)
   Sum := Sum * PowerTerm; (* Last calculation *)
   WriteString("Bessel Function = ");
   WriteReal(Sum,14); WriteLn; WriteLn;

END BesselFunction.
```

Each **EXIT** statement resumes program flow after the exited loop body. Therefore, to exit nested open loops one needs as many exit statements as there are loops.

2.4 Functions and Procedures

Modula-2 considers a function as merely a procedure returning a value. Thus, the keyword **FUNCTION** has been dropped and replaced with **PROCEDURE**. The other change implements a **RETURN** statement that exits the function and returns the sought value. If there are any statements after the **RETURN**, they will not be executed. ***LOGITECH Modula-2*, Version 3.0**, functions only return basic types and pointers.

Consider the following examples of a function to calculate the square root of a real number, using Newton's iterative method.

```
PROCEDURE SquareRoot(X : REAL) : REAL;

CONST Epsilon = 1.0E-08; (* Tolerance factor *)

VAR Y : REAL; (* Local storage for square root *)

   BEGIN
      Y := X / 2.; (* Initial guess for square root *)
      REPEAT (* Improve guess by Newton's iterations *)
          Y = (Y + X / Y) / 2.;
      UNTIL ABS(Y*Y - X) < Epsilon;
      RETURN Y (* back to caller *);
END SquareRoot;
```

An additional difference between the two languages, is that *Modula-2* requires all procedures and functions to include their names after the last **END** in the subprogram.

Like *Pascal*, *Modula-2* allows parameter passing by value or by reference (using **VAR** declaration). The latter makes it possible to simulate a function that returns structured data types. *Modula-2* has implemented an important new feature in parameter passing -- open arrays. This enables procedures (and functions) to tackle arrays of consistent type, but varying in size. This makes it easier to write general purpose routines in *Modula-2*. Open arrays are limited to one dimensional arrays. They are declared in an argument list as **ARRAY OF `<type>`**, with no dimension limits. Inside the procedure body the dimension bounds are mapped onto `[0..<array size - 1>]`. *Modula-2* provides the predefined **HIGH()** function to return the upper bound value for an open array. Thus an open array is mapped onto `[0..HIGH(<Open array name>)]`.

Here is an example for a routine to calculate the mean value of an array of reals.

```
PROCEDURE Mean(X : ARRAY OF REAL) : REAL;

VAR i   : CARDINAL;
    Sum : REAL;

   BEGIN
      Sum := 0.; (Initialize sum *)
      FOR i   := 0 TO HIGH(X) DO
          Sum := Sum + X[i];
      END;
      RETURN Sum / FLOAT(HIGH(X) + 1);
END Mean;
```

Function **Mean** is able to handle arrays of varying sizes. The number of elements in the passed array X is (HIGH(X) + 1). This assumes that the entire array X is filled with data.

Procedural and functional types are supported in ***Modula-2***. The following example demonstrates the first type. The program below reads an array of cardinals from a file and sorts them. The sorting routines are imported. The program examines the list size and depending on its value employs the appropriate sorting method. For small arrays, the bubble sort is used. For medium arrays the **Shell** sort is called upon. **QuickSort** is reserved for large arrays. To demonstrate the procedural type, the program defines **SortProc**. It is a procedure taking two arguments: an array of cardinal and a scalar type cardinal. The variable **SortMethod** is of **SortProc** type. In the **IF** statement we assign either imported sorting procedure to **SortMethod**. Notice that the assignment does not involve any procedural arguments. Following the **IF** statement is a call to **SortMethod** with a complete argument list. The call will execute the assigned procedure (**BubbleSort**, **ShellSort** or **QuickSort**).

Here is the program:

```
MODULE Sort;

FROM InOut          IMPORT WriteString, ReadString, WriteCard, WriteLn;
(* Modules FileIO and CardinalSortLib are fictitious *)
FROM MyFileIO       IMPORT TextFile, EOF, Assign, Reset, ReadCardinal, Close;
FROM CardinalSortLib IMPORT ShellSort, QuickSort, BubbleSort;

(* Define a procedure type with an array of cardinals  *)
(* and a scalar cardinal as arguments.         *)
(* Imported sorting procedures must have same arguments *)

TYPE SortProc = PROCEDURE(VAR ARRAY OF CARDINAL;CARDINAL);

VAR CardinalList : ARRAY [1..5000] OF CARDINAL;
    Num, i       : CARDINAL;
    Filename     : ARRAY [1..14] OF CHAR;
    F            : TextFile
    SortMethod   : SortProc;

BEGIN
    WriteString("Enter data filename ");
    ReadString(Filename)
    Assign(TextFile,Filename);
    Reset(F)
    Num := 0;
    WHILE NOT EOF(F) DO
       INC(Num);
       ReadCardinal(F,CardinalList[Num]);
   END;
   Close(F);
   IF Num <= 30 THEN
     (* Small list, use bubble sort *)
     SortMethod := BubbleSort  (* No arguments *)
   ELSIF Num <= 150 THEN (* Medium list => Shell sort *)
     SortMethod := ShellSort  (* No arguments *)
   ELSE (* QuickSort used for large array *)
     SortMethod := QuickSort (* No arguments *);
   END;

   SortMethod(CardinalList, Num); (* Sort list *)

   FOR i := 1 TO Num DO (* Display sorted list *)
      WriteCard   (i,5);
      WriteString ('  ');
      WriteCard   (CardinalList[i],6);
      WriteLn;
  END;

END Sort.
```

Modula-2 provides **PROC**, a predefined parameterless procedure type. This is useful in creating coroutines, which are discussed later.

Predefined functions and procedures are listed in Wirth's ***Programming in Modula-2***.

2.5 Use of Modules

2.5.1 User Definable Modules

Modula-2 implements library modules to benefit software productivity. This affects both the individual programmer and a team of programmers working on a big project. One of the advantages of library modules is that they minimize side effects between modules written by different programmers or written at different times. This reduces debugging greatly and significantly improves on software maintainability.

The virtue of modules stems from the fact that inter-module communication is spelled out and is not ambiguous. This is done by specifying the objects exported and imported. As we have seen in previous *Modula-2* programs, there are invariably lists of imports. Each specifies the module from which to import and the specific procedures imported. If the reader looks at the definition module of, for example, module **InOut**, he will find all the imported items defined in that module (i.e. marked for export). *Modula-2* works on the principle that you can obtain an item only if it is made available to you.

In *Modula-2* a library module is made up of two parts: the definition and the implementation modules. The definition module is regarded as the interface with client modules. All exported objects are catalogued there. This includes constants, data types, variables and procedures. The implementation module has all the detailed exported procedure code and additional local constants, data types, variables and procedures. Optional module initialization code lines may be included. Each of the definition and implementation modules are compiled separately. The programmer may "improve" on the implementation module by replacing old algorithms with more efficient ones. As long as the exported objects are not altered, we only need to recompile the implementation module.

Consider the following example to demonstrate some of the above points. We present a small library module to create and add complex numbers. The definition module is:

```
DEFINITION MODULE ComplexOps;

EXPORT QUALIFIED
      Complex,                 (* Type *)
      MakeComplex, AddComplex; (* Procedures *)

   TYPE Complex = RECORD Real, Imaginary : REAL; END;

   (* Only procedure headings are needed *)

PROCEDURE MakeComplex(X, Y : REAL;    (* Input *)
                     VAR C : Complex (* Output *))
   (* Procedure to create a complex number from X & Y components. *)

PROCEDURE AddComplex (A, B  : Complex; (* Input  *)
                      VAR C : Complex  (* Output *));
   (* Procedure to add complex numbers A & B to give C *);

END ComplexOps.
```

The definition module **ComplexOps** exports the "transparent" type **Complex.** The terminology refers to types whose definition is made available to client modules. ***Modula-2*** also allows the export of "opaque" types, where the data type definition is not revealed. We will discuss this in more detail later. For now, it is enough to say that there is the following difference between transparent and opaque types: the ability of the client modules to have their own procedures (possibly available for export) to manipulate the transparent types only. This privilege is denied with opaque types. Thus clients modules of **ComplexOps** can develop and export procedure to subtract, divide and multiply complex numbers. Their access to the components of type **Complex** makes it possible.

In general, definition modules need only the heading of the exported procedures, and the definition module **ComplexOps** is no exception. In practice, the definition module should be the first one written to set the module specification. In large software projects this is the appropriate thing to do.

The implementation module is:

```
   IMPLEMENTATION MODULE ComplexOps;

   (* Type Complex has been defined in the definition module *)

   PROCEDURE MakeComplex ( X, Y  : REAL;    (* Input  *)
                           VAR C : Complex (* Output *) )

   (* Procedure to create a complex number from X & Y *)
   (* components.                      *)
   BEGIN
     C.Real      := X;
     C.Imaginary := Y;
   END MakeComplex;


   PROCEDURE AddComplex( A, B  : Complex; (* Input  *)
                         VAR C : Complex  (* Output *) );
   (* Procedure to add complex numbers A & B to give C *)
   BEGIN
     C.Real      := A.Real      + B.Real;
     C.Imaginary := A.Imaginary + B.Imaginary;
   END AddComplex;

END ComplexOps.
```

The implementation module does not contain the definition of type **Complex**. Since it is exported, the compiler is already aware of it through the definition module. The exported procedures are listed in the module. All the imported objects needed in each module need to be explicitly imported regardless, if it is a definition module, an implementation module, or a program module. Otherwise, import lists are located in the implementation module. Local constants, data types, variables and procedures are of course included in the implementation module.

We spoke earlier of the ability to change and improve the code in the implementation module. In certain cases this may require that exported transparent data types be modified. This poses a problem since transparent types give library module developers little or no control over how client modules use them. Most likely the sought improvement may be hindered because of potential data type incompatibility between the old and new structures. A new sister module is created. However this solution is not always a sound way to go.

While the above discussion refers to a rather specific case, it also points to a broader programming aspect: full control over exported data types. ***Modula-2*** has met this need by allowing opaque exported types. In this case the definition module lists the name of the opaque type only. No type structure is defined there. Instead, it is located in the implementation module. With the details about the structure denied to client modules, the exporting module has the monopoly on procedures that manipulate opaque types. Thus, with full control over opaque types comes the responsibility to export every procedure needed to process the data types in question. Care in planning ahead must be exercised.

Return to the complex number addition module. Complex numbers may be represented by two dimensional rectangular coordinates (X,Y). Alternatively, the same (X,Y) point can be replaced by polar coordinates: a modulus and an angle. While the two systems are equivalent, their components represent different physical entities. It is possible to develop a library of complex operations using rectangular coordinates and later change the implementation module to use polar ones. An opaque complex type makes the smooth transition.

Below is the new definition module for **ComplexOps**. Notice that the exported type **Complex** has no structure definition associated with it.

```
DEFINITION MODULE ComplexOps;
   FROM Storage IMPORT ALLOCATE;

   EXPORT QUALIFIED
     Complex,                 (* Type *)
     MakeComplex, AddComplex; (* Procedures *)

   TYPE Complex;              (* Is now opaque *)
   (* Only procedure headings are needed *)

   PROCEDURE MakeComplex( X, Y  : REAL;    (* Input  *)
                          VAR C : Complex (* Output *))
   (* Procedure to create a complex number from X & Y components. *)

   PROCEDURE AddComplex( A, B  : Complex; (* Input  *)
                         VAR C : Complex  (* Output *));
   (* Procedure to add complex numbers A & B to give C *);

   END ComplexOps.
```

The implementation module is similar to the previous version. Within it the **Complex** type is now fully defined. The fields of the type **Complex** have been renamed to remind the reader that rectangular coordinates are used to represent complex numbers. Notice that opaque types must be pointer to other structures. This is mandatory in ***Modula-2***.

```
IMPLEMENTATION MODULE ComplexOps;
   FROM Storage IMPORT ALLOCATE;

   (* Type Complex uses rectangular coordinates *)
   TYPE Complex = POINTER TO RECORD
                  XCoord, YCoord : REAL;
   END;

   PROCEDURE MakeComplex( X, Y  : REAL;    (* Input  *)
                          VAR C : Complex (* Output *))

   (* Procedure to create a complex number from X & Y components.*)
      BEGIN
         NEW(C);
            C^.XCoord := X;
            C^.YCoord := Y;
   END MakeComplex;


   PROCEDURE AddComplex (A, B  : Complex; (* Input  *)
                         VAR C : Complex  (* Output *));
   (* Procedure to add complex numbers A & B to give C *)
       BEGIN
          C^.XCoord := A^.XCoord + B^.XCoord;
          C^.YCoord := A^.YCoord + B^.YCoord;
   END AddComplex;

END ComplexOps.
```

Here is the implementation module version that uses polar coordinates:

```
IMPLEMENTATION MODULE ComplexOps;
   FROM Storage IMPORT ALLOCATE;

   FROM MathLib0 IMPORT sqrt, arctan, sin, cos;

   (* Type Complex uses polar coordinates *)

   TYPE Complex = POINTER TO RECORD
                    Modulus, Angle : REAL;
   END;

PROCEDURE MakeComplex ( X, Y  : REAL;     (* Input  *)
                        VAR C : Complex   (* Output *))

(* Procedure to create a complex number from X & Y components. *)
   BEGIN
     NEW(C);
     C^.Modulus := sqrt(X * X  +  Y * Y);
     C^.Angle   := arctan(Y / X);
END MakeComplex;


PROCEDURE AddComplex ( A, B  : Complex; (* Input  *)
                       VAR C : Complex  (* Output *));
(* Procedure to add complex numbers A & B to give C *)

   VAR X, Y : REAL;

   BEGIN
      X := A^.Modulus * cos(A^.Angle) + B^.Modulus * cos(B^.Angle);
      Y := A^.Modulus * sin(A^.Angle) + B^.Modulus * sin(B^.Angle);
      MakeComplex(X, Y, C);
END AddComplex;

END ComplexOps.
```

The following changes took place:

- Four required mathematical functions are imported from **MathLib0**.
- The **Complex** type is defined using the **Modulus** and **Angle** fields.
- The body of the two module procedures has been significantly changed.
- Procedure **AddComplex** now calls procedure **MakeComplex**.

Note: the **MakeComplex** procedure in the very first implementation seemed an extravagant export: given the definition of **Complex**, client programs can assign values to the record fields effortlessly. The situation is reversed with the opaque **Complex**: client modules now really need procedure **MakeComplex**, since they have no idea about its internal structure. The rectangular and polar versions demonstrate this point.

2.5.2 Importing Procedures with Identical Names

With the incentive to develop library modules it is inevitable that the same procedure names appear in more than one module. How do we resolve the conflict due to importing two identically named routines? It is possible to omit the import list, thus importing the entire library. To use the imported routine we use the same notation as with referencing fields of record structures. With the module name constantly referenced, the compiler is able to distinguish which procedure we are calling. Moreover, the program readability will enjoy the clarity too. Consider the following example.

```
MODULE ImportAllDemo

   IMPORT InOut;
   IMPORT MyFileIO;

   VAR Filename : ARRAY [1..14] OF CHAR;
       F        : MyFileIO.TextFile; (* Imported type *)
       Message  : ARRAY [1..80] OF CHAR;
       NumLines : CARDINAL;

      BEGIN;
          InOut.WriteString("Enter file name ");
          InOut.ReadString(Filename);
          InOut.WriteLn;
          REPEAT
               InOut.WriteString("Enter number of lines ");
               InOut.ReadCard(NumLines);
               InOut.WriteLn;
          UNTIL NumLines > 0;

          MyFileIO.Assign(F,Filename);
          MyFileIO.Reset(F);
          InOut.WriteString("Enter text ");
          InOut.WriteLn;
          REPEAT
              InOut.ReadString(Message);
              MyFileIO.WriteString(F,Message);
              DEC(NumLines);
          UNTIL NumLines = 0;
          MyFileIO.Close(F);

END ImportAllDemo.
```

In the above example we can distinguish for each call to procedure **WriteString** whether it is imported from modules **InOut** or **MyFileIO**.

2.5.3 Standard Library Modules

LOGITECH Modula-2 comes with a variety of versatile library modules. They supply your programs with a wide gamut of capabilities. This includes string manipulation, file I/O, disk directory access, data conversions, mathematical functions, *DOS* and low level access, coroutines, just to name a few. Many of the above routines are part of *Pascal*, but not *Modula-2*. Thus *Modula-2* depends heavily on a core or fundamental library modules. The reader is referred to other parts of the manual where the definition modules are discussed.

There are three small but very important modules -- **SYSTEM**, **Storage** and **Processes**. We will discuss these modules because they export low level and process management routines.

The module **Storage** tackles the allocation and deallocation of dynamic variables. **ALLOCATE** and **DEALLOCATE** procedures are defined as:

```
PROCEDURE ALLOCATE    (VAR a : ADDRESS; size : CARDINAL)
PROCEDURE DEALLOCATE  (VAR a : ADDRESS; size : CARDINAL)
```

where **ADDRESS** is a pointer to a memory location imported from module **SYSTEM**. These are equivalent to calling the **NEW** and **DISPOSE** procedures used for the same purpose. The following demonstrates how the two sets of procedures work identically. Let us define the following data types and variable.

```
TYPE Ptr     = POINTER TO Element;
     Element = RECORD
                  Volume, Weight : REAL;
                  Name           : ARRAY [1..80] OF CHAR;
END;

VAR Indicator : Ptr;
```

Calling **NEW(Indicator)** and **ALLOCATE(Indicator, TSIZE(Element))** yield the same result: creating a dynamic variable accessed through the pointer **Indicator**. **TSIZE()** is a function imported from module **SYSTEM** that returns the size of any data type. Similarly, **DISPOSE(Indicator)** and **DEALLOCATE(Indicator, TSIZE(Element))** both undo the effect of the above procedures.

Let us demonstrate the use of the **ALLOCATE** and **DEALLOCATE** procedures in developing a short dynamic string library module.

```
DEFINITION MODULE DynamicString;

     EXPORT QUALIFIED STRING, NewString, RemoveString, AssignString, Length;

     TYPE STRING; (* Opaque type *)

     PROCEDURE NewString ( VAR S      : STRING;    (* Output *)
                           MaxLength : CARDINAL   (* Input  *));
     (* Create a dynamic string *)


     PROCEDURE RemoveString ( VAR S : STRING; (* Input *));
     (* Remove a dynamic string *)

     PROCEDURE AssignString ( VAR S : STRING;        (* Output *)
                              A     : ARRAY OF CHAR (* Input  *))
     (* assign an array of characters to a STRING *)

     PROCEDURE Length ( S : STRING) : CARDINAL;
     (* Function to return string length *);

END DynamicString.
```

The implementation module is:

```
IMPLEMENTATION MODULE DynamicString

     FROM SYSTEM  IMPORT  ADDRESS, TSIZE;
     FROM Storage IMPORT  ALLOCATE, DEALLOCATE;

     TYPE STRING = POINTER TO RECORD
                      Long,
                      MaxLong : CARDINAL;
                      Element : ADDRESS;
     END;

     PROCEDURE NewString ( VAR S      : STRING;    (* Output *)
                           MaxLength : CARDINAL   (* Input  *));
     (* Create a dynamic string *)

     BEGIN
        NEW(S);
           WITH S DO
              Long := 0;
              MaxLong := MaxLength;
           ALLOCATE ( Element, + MaxLong);
      END;
   END NewString;
```

```
PROCEDURE RemoveString(VAR S : STRING; (* Input *));
(* Remove a dynamic string *)

   BEGIN
      WITH S DO
         DEALLOCATE(Element, + MaxLong);
   END;
   DISPOSE(S);
END RemoveString;

     PROCEDURE AssignString ( VAR S : STRING;       (* Output *)
                              A     : ARRAY OF CHAR (* Input  *))
     (* assign an array of characters to a STRING *)

     VAR Ptr : POINTER TO CHAR;

     BEGIN
        IF A[0] <> 0C
           THEN i := 0;
              WHILE (i <= HIGH(A)) AND (A[i] <> 0C)
                 AND (S^.MaxLong>= (i*TSIZE(CHAR)))
              DO
                  Ptr  :=S^.Element + i * TSIZE(CHAR);
                  Ptr^ := A[i];
                 INC(i);
               END;
         S^.Long := i + 1;
            ELSE
               S^.Long := 0 (* Empty string *);
   END;
END AssignString;


PROCEDURE Length(S : STRING) : CARDINAL;
(* Function to return string length *)

   BEGIN
       RETURN S^.Long;
   END Length;

END DynamicString.
```

The next module we examine is **SYSTEM.** It exports four data types: **BYTE, WORD, ADDRESS** and **PROCESS.** The type **WORD** corresponds to one hardware storage unit. For example, the types **CARDINAL** and **INTEGER** use one **WORD** of storage. The type **ADDRESS** is defined as **POINTER TO WORD.** The type **PROCESS** is used in declaring coroutines.

The type **WORD** opens the door for some data conversion and the creation of general purpose (generic) routines. Recall that ***Modula-2*** routines accept open arrays of any type in their argument lists. The **ARRAY OF WORD** is no exception and is compatible with any type, scalar or otherwise.

In the first example of using **WORD** we demonstrate the compatibility between **CARDINAL** and **INTEGER.** Each type occupies one **WORD** of storage, a key feature in the example. The following procedure searches an array of either types. The index of the matched element is returned. A boolean flag is used to indicate whether the returned value reflects a successful search. We assume that the array values are in the range [0..32767], the common value range for integers and cardinals.

```
PROCEDURE SearchArray ( A         : ARRAY OF WORD; (* Input  *)
                        S         : WORD           (* Input  *)
                        VAR Found : BOOLEAN        (* Output *) ) : CARDINAL;

VAR i, SoughtValue : CARDINAL;

   BEGIN
      Found        := FALSE; (* Default outcome *)
      i            := 0;     (* Zero search index *)
      SoughtValue  := CARDINAL(S);
   WHILE (i <= HIGH(A)) AND (NOT Found) DO
   IF CARDINAL(A[i]) = SoughtValue THEN (* Found it! *)
      Found := TRUE
   ELSE (* Next element? *)
        INC(i);
      END;
   END; (* WHILE *)
      RETURN i;
END SearchArray;
```

Using **ARRAY OF WORD** to create generic modules is more elaborate when handling multi-word data structures. Since the processed object size varies, we must supply a single "sample" type in the generic procedure argument list. The above sample type is used as a template to determine the type size and provide local scalar variables. Another set of needed parameters is the user-supplied operations, such as comparisons, performed on the data objects. This is supplied in the form of procedural or functional parameters.

Here is a simple procedure to perform a generic linear list search on an array:

```
PROCEDURE GenericLookUp ( VAR SearchArray              : ARRAY OF WORD;
                          SampleScalarType, SearchValue  : ARRAY OF WORD;
                          IsItEqual                      : SuppliedPROC;
                          VAR Found                      : BOOLEAN) : CARDINAL;
                          VAR Num, TypeSize, SearchIndex : CARDINAL;

PROCEDURE GetElement ( Index      : CARDINAL;
                       VAR Object : ARRAY OF WORD);
   (* Procedure to extract one object *)
                       VAR i      : CARDINAL;

   BEGIN
      FOR i         := 0 TO TypeSize-1 DO
          Object[i] := SearchArray[(Index*TypeSize + i);
   END;
END GetElement;

   BEGIN
      TypeSize    := HIGH(SampleScalarType) + 1;
      Num         := (HIGH(SearchArray) + 1) DIV TypeSize;
      SearchIndex := 0;
      Found       := FALSE;
      WHILE (SearchIndex < Num) AND (NOT Found)
         DO  GetElement(SearchIndex, SampleScalarType);
      IF IsItEqual(SampleScalarType, SearchValue)
         THEN Found := TRUE
      ELSE
         INC(SearchIndex);
      END;
   END;
   RETURN SearchIndex;
END GenericLookUp;
```

In the above example we supply an array of objects via **SearchArray**. The **SearchValue** and **SampleScalarType** variables supply the searched value and an additional internally needed copy of the single object. The local procedure **GetElement** is used to extract a member of the search array and save it into **SampleScalarType**. The user-supplied function **IsItEqual** is used in comparing the search value with an array element.

Below is a sample for the **IsItEqual** function dealing with date records. Local pointers are used to access the record structure in question. Once the pointer addresses are assigned, the **RETURN** statement supplies the logical result for the two-field test.

```
PROCEDURE IsItEqual(Element1,
                              Element2 : ARRAY OF WORD) : BOOLEAN;

VAR Ptr1, Ptr2 : POINTER TO RECORD
                    DayNumber, MonthNumber : CARDINAL;
                                     END;
BEGIN
     (* Get pointers addresses *)
     Ptr1 := ADR(Element1);
     Ptr2 := ADR(Element2);
     RETURN ((Ptr1^.DayNumber = Ptr2^.DayNumber) AND
                    (Ptr1^.MonthNumber = Ptr2^.MonthNumber));
END IsItEqual;
```

Module **SYSTEM** has three address related functions. **ADR(Z)** returns the address of identifier **Z**. Functions **SIZE** and **TSIZE** return the sizes of a variable and data type, respectively. The rest of the exported routines tackle concurrency.

Consider the following simple example. It continuously displays the messages "**In Coroutine <n>**", where **<n>** follows the sequence [**1,2,3**].

```
MODULE ConcurrentDemo;

FROM InOut    IMPORT   WriteString, WriteLn;
FROM SYSTEM   IMPORT   WORD, PROCESS, ADR, SIZE, NEWPROCESS, TRANSFER;

VAR main, Coroutine1, Coroutine2, Coroutine3    : PROCESS;
          WorkSpace1, WorkSpace2, WorkSpace3    : ARRAY [1..200] OF WORD;
          (* Workspace *)

PROCEDURE Message1;
   BEGIN
      LOOP
         WriteString("In Coroutine # 1");
         WriteLn;
      TRANSFER(Coroutine1, Coroutine2);
   END;
END Message1;


PROCEDURE Message2;
   BEGIN
      LOOP
         WriteString("In Coroutine # 2");
         WriteLn;
         TRANSFER(Coroutine2, Coroutine3);
   END;
END Message2;


PROCEDURE Message3;
   BEGIN
       LOOP
          WriteString("In Coroutine # 3");
          WriteLn;
          TRANSFER(Coroutine3, Coroutine1);
   END;
END Message3;

    BEGIN (* main *)
          (* Create the new Coroutines *)
          NEWPROCESS(Message1, ADR(WorkSpace1), SIZE(WorkSpace1), Coroutine1);
          NEWPROCESS(Message2, ADR(WorkSpace2), SIZE(WorkSpace2), Coroutine2);
          NEWPROCESS(Message3, ADR(WorkSpace3), SIZE(WorkSpace3), Coroutine3);
          TRANSFER(main, Coroutine1);

END ConcurrentDemo.
```

The previous program shows that each co-routine is created using the **NEWPROCESS** procedure taking the following arguments:

- Parameterless procedure name. The procedure must be at the top level in the module and not nested within another routine.
- The address of a coroutine workspace (for stacks and other items).
- Size of the workspace.
- A **PROCESS** typed variable to be associated with the coroutine name.

Our example uses three variables, each 200 WORDS long, to reserve the needed workspaces. An alternate route is to dynamically allocate the workspace sizes.

The coroutine example also shows how coroutines are activated. The **TRANSFER** procedure is used to request the activation of a new coroutine while suspending the old one. When **ConcurrentDemo** first runs, the three coroutines are created. Next, the main section transfers the attention of the CPU to the first coroutine and suspends itself. An infinite sequence of tasks begins. Each coroutine displays a message and transfer CPU control to another coroutine, and so on. Coroutine procedures are parameterless, as stated earlier, and contain their code inside an infinite open loop.

IOTRANSFER is another procedure exported by **SYSTEM** and works similar to **TRANSFER.** It is oriented towards tackling device interrupts. Since these interrupts take place beyond the program's control, there must be an automatic way to handle them. **IOTRANSFER** shifts the control from a first process to a second one, but is able to resume the first when an interrupt occurs. **IOTRANSFER** takes a third parameter, the interrupt vector number. Module **SYSTEM** also exports procedure **LISTEN.** This causes the coroutine to wait for an **IOTRANSFER** to take place.

Synchronization between coroutines is vital in keeping their liveliness. This assures that every process maintains its vitality. Using a single CPU, each process must run for a short period of time and then be suspended to allow others to resume likewise. The above coordination becomes more critical when the same data is accessed by more than one coroutine. In this case it is imperative to ensure that only one process manipulate data. This means that other coroutines must wait for their turn to access the same data. The overall picture depicts two waiting queues: one for processes simply waiting their turn to use the CPU, the other for processes waiting to access a critical data item.

The **Processes** module exports items needed to accomplish the above sought synchronization. The definition module is:

```
DEFINITION MODULE Processes;

   EXPORT QUALIFIED SIGNAL, init, SEND, WAIT, Awaited, StartProcess;

   TYPE SIGNAL; (* Opaque type used by processes to communicate with each other *)

   PROCEDURE Init(VAR S : SIGNAL); (* Initialize signal *)

   PROCEDURE SEND(VAR S : SIGNAL); (* Send signal *)

   PROCEDURE WAIT(VAR S : SIGNAL); (* Wait for signal *)

   PROCEDURE Awaited(S : SIGNAL) : BOOLEAN;
   (* Function to return if a signal is awaited *)

   PROCEDURE StartProcess(P : PROC; WorkSpace : CARDINAL);
   (* Start process P with WorkSpace bytes *);

END Processes.
```

In the above module, type **SIGNAL** is used for process inter-communication. Procedure **Init** is used to initialize a signal. Procedure **WAIT** suspends a process while waiting for a particular signal to be sent (using **SEND**) by another process.

To demonstrate how the above data type and procedures are used, consider the following program, which takes an array of reals from the keyboard and calculates the corresponding average and standard deviation values. These statistics are evaluated using the sums of the observations and their squared values which can be evaluated concurrently. A coroutine is employed to update the sum of squares, while the main program calculates the sum of observations. Since each array element is accessed by the main program and the coroutine, we need to synchronize their access.

Let's look at the listing and then resume our discussion.

```
MODULE Synchronicity;

   FROM Processes   IMPORT SIGNAL, Init, SEND, WAIT, StartProcess;
   FROM InOut       IMPORT WriteString, WriteLn, ReadCard, WriteCard;
   FROM RealInOut   IMPORT ReadReal, WriteReal;
   FROM MathLib0    IMPORT sqrt;

   CONST MAX = 100;

   VAR Count, NumData                     : CARDINAL;
       GoAheadMakeMyDay                   : SIGNAL;
       SumX, SumXX, Average, StdDeviation : REAL;
       X                                  : ARRAY [1..MAX] OF REAL;

   PROCEDURE GetSumSquare;
   (* Process to calculate sum of data squares *)

      BEGIN
         (* Message displayed first time process is invoked *)
         WriteString('Start squaring');
         WriteLn;
         LOOP
              WAIT(GoAheadMakeMyDay); (* wait for a go signal *)
              WriteString ('Squaring observation # ');
              WriteCard (Count,4);
              WriteLn;
              SumXX := SumXX + X[Count] * X[Count];
      END;
   END GetSumSquare;
   PROCEDURE GetData;

   VAR i : CARDINAL;

      BEGIN
         REPEAT
            WriteString('Enter number of data (<100) ');
            ReadCard(Numdata)
         UNTIL (NumData <= MAX) AND (NumData > 2);

         FOR i := 1 TO NumData DO
            WriteString('Enter observation # ');
            WriteCard(i,4);
            WriteString('    ');
            ReadReal(X[i]);
            WriteLn;
      END;
   END GetData;

   BEGIN
      GetData;
      WriteString('All data entered');
      WriteLn;
      Init(GoAheadMakeMyDay);
      (* Initialize counter and statistical summations *)
      Count := 1;
      SumX  :=0.0;
      SumXX := 0.0;
      StartProcess(GetSumSquare,600);
      SEND(GoAheadMakeMyDay);
      LOOP
          WriteString('Summing observation # ');
          WriteCard(Count,4);
          WriteLn;
          SumX := SumX + X[Count];
          INC(Count); (* Increment global data counter *)
          (* Are all the observations processed? *)
          IF Count > NumData THEN EXIT END;
          (* Signal for GetSumSquare process to resume *)
          SEND(GoAheadMakeMyDay);
      END;
          Average      := SumX / FLOAT(NumData);
          StdDeviation := sqrt((SumXX - SumX * SumX /
                                FLOAT(NumData)) /
                                (FLOAT(NumData - 1));
          WriteString('Average = ');
          WriteReal(Average,14);
          WriteLn;
          WriteString('Standard Deviation = ');
          WriteReal(StdDeviation,14);
          WriteLn;
END Synchronicity.
```

When the program starts it first prompts for keyboard data entry, performed by procedure **GetData**. The main program proceeds with a confirmation message followed by initializing the process signal. After the appropriate variable initializations process **GetSumSquare** is triggered. In turn it displays the "`Start squaring`" message once and waits for a signal. The control is briefly transferred back to the main program only to execute the **SEND** procedure and return us to the coroutine. The open loop is resumed and the message "`Squaring observation 1`" is displayed followed by the first update of the sum of squares. Having accessed the first array member, X[1], the coroutine signals to the main program for it to resume. The message "`Summing observation 1`" is displayed, sum updated and counter incremented. This is followed by a test to determine if all the data have been processed and the loop is accordingly exited. Otherwise the main program signals the coroutine to perform its task and another cycle of calculations is executed.

Chapter 3
The Compiler

The *LOGITECH Modula-2 Compiler* translates an *ASCII* text file with an extension of either .DEF or .MOD written in high level *Modula-2* code — into a linkable object file with an extension of .OBJ containing low level machine code.

There are two versions of the *LOGITECH* compiler — a fully linked version, and an overlay version.

M2C.EXE is the fully linked version.

M2COMP.EXE is the overlay version and consists of a base file and six overlay files. This version uses less memory and so takes longer to compile a given module than M2C.EXE, but may be useful when memory is limited due to hardware or due to other applications present in memory at the same time.

3.1 How to Use the Compiler

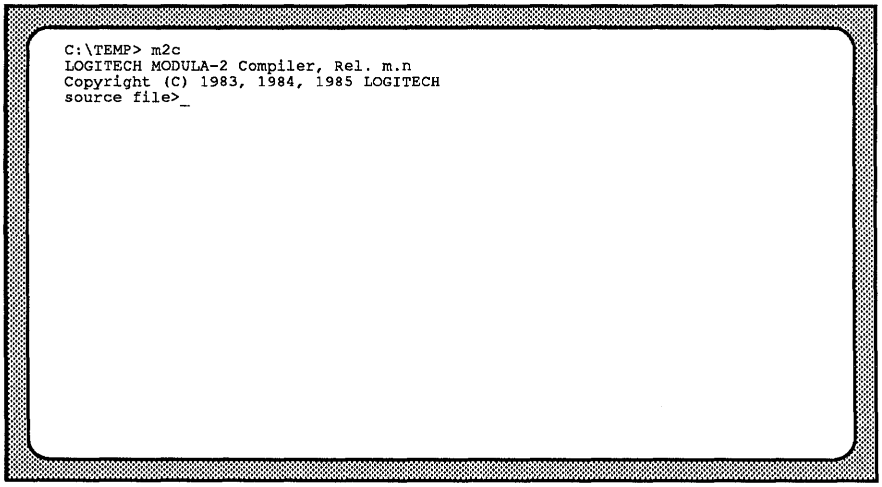
To run the fully-linked version of the compiler, type:

M2C ↵

To run the overlay version of the compiler, type:

M2COMP ↵

If you are compiling with M2C.EXE from the *DOS* command line, you will see the banner with the version number and a prompt for the name of the module to be compiled:



```
C:\TEMP> m2c
LOGITECH MODULA-2 Compiler, Rel. m.n
Copyright (C) 1983, 1984, 1985 LOGITECH
source file>_
```

Enter the filename and any options (see <u>Section 3.8</u> on compiler options). The default drive is the current disk and the default extension for program and implementation modules is .MOD .

When this module is compiled, the compiler asks for another module. At this point, you can enter another filename or terminate the compiler by pressing Esc .

You can also run the compiler by typing the filename(s) on the command line, thus:

M2COMP (or **M2C**) <File 1> <File 2> ... <File X> ↵

In this case the compiler will compile all the files in the specified order. At the end it returns automatically to *DOS* without any further request for source files.

NOTE

If you use the `M2ASSIST` environment in *POINT*, you will see a compile options prompt on the bottom line of the screen.

As soon as you enter the necessary options, you will see a new screen with information similar to that on the previous page.

To compile more than one file at a time with *POINT*:

Step 1: Save the file(s) to be compiled;
Step 2: Type the complete compile command on a scratch screen;
Step 3: Select `Execute Selected Command` from the `QUIT+ETC` menu.

3.2 Compiler Organization

The overlay version of the compiler is organized as a base part and several passes or ‘overlays’. The base part remains in memory during the entire compilation and calls the passes sequentially. When loading these passes, the compiler assumes they are on the same drive as M2COMP.EXE, the compiler base.

The necessary overlay files are:

M2COMP.EXE	compiler base
M2OVLINI.OVL	initialization
M2OVL1.OVL	syntax analysis and declaration
M2OVL2.OVL	block analysis
M2OVL3.OVL	code generation
M2OVLSYM.OVL	symbol file generation
M2OVLLIS.OVL	lister

The fully linked version of the compiler is the single file M2C.EXE.

NOTE

During compilation, temporary work files are created on the current drive and directory, or where the environment variable M2TMP specifies. (You may specify a RAM disk to increase compilation speed.) These files are deleted before compilation ends.

3.3 Compiler Output Files

Several files are generated by the compiler. They are created in the current directory and are given the same file name as the source file, but with the appropriate extension:

.SYM **Symbol file**

Compiler output file with symbol table information. This information is generated during compilation of a definition module.

.REF **Reference file**

Compiler output file with debugger information, generated during compilation of an implementation or a program module.

.OBJ **Object file**

Compiler output file with generated 8086 object code in linker format, generated during compilation of implementation or program module.

.LST **Listing file**

Normally generated only if errors occur.

3.4 Compilation of a Program Module

Compilation of a program module *in which there are no errors* generates a linkable object (.OBJ) file, and a debug reference (.REF) file.

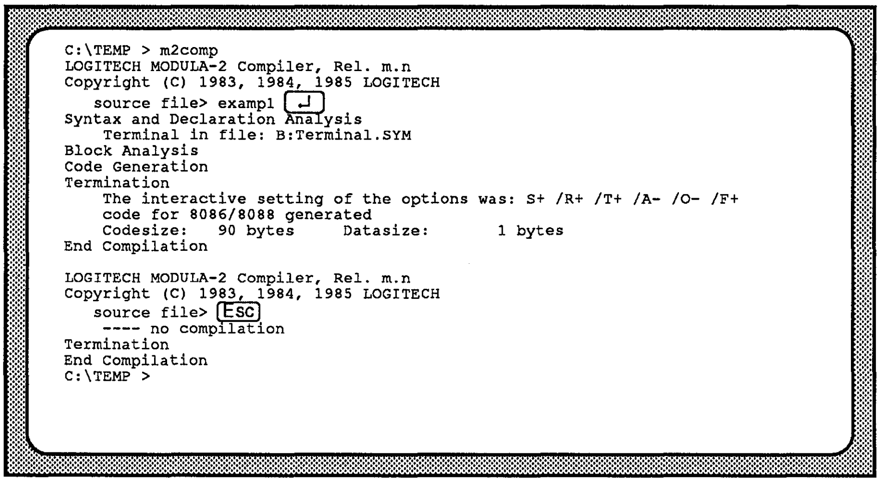
If there are errors, the link and reference files are not produced, but a listing (.LST) file is produced.

The **L** option (see <u>Section 3.8</u> on compiler options, below) tells the compiler to generate a listing file *even if there are no errors.*

Thus, if you type

M2COMP ↵

you get a screen that looks like this:



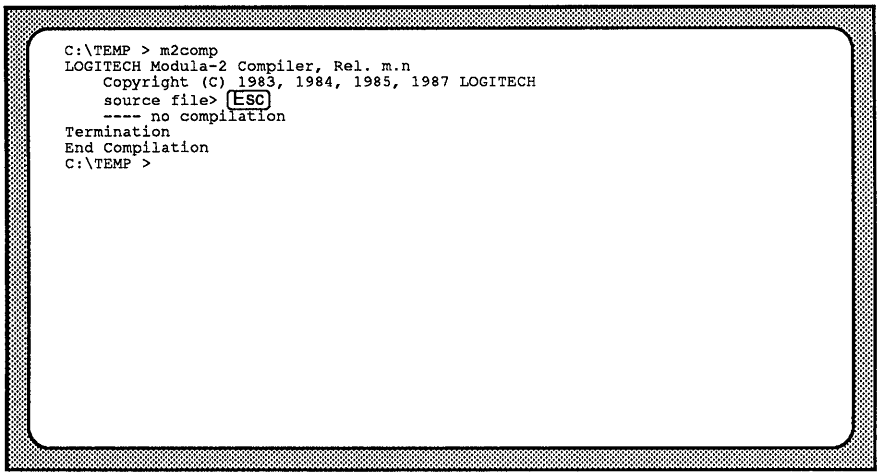
```
C:\TEMP > m2comp
LOGITECH MODULA-2 Compiler, Rel. m.n
Copyright (C) 1983, 1984, 1985 LOGITECH
   source file> exampl ↵
Syntax and Declaration Analysis
    Terminal in file: B:Terminal.SYM
Block Analysis
Code Generation
Termination
    The interactive setting of the options was: S+ /R+ /T+ /A- /O- /F+
    code for 8086/8088 generated
    Codesize:   90 bytes     Datasize:       1 bytes
End Compilation

LOGITECH MODULA-2 Compiler, Rel. m.n
Copyright (C) 1983, 1984, 1985 LOGITECH
   source file> Esc
    ---- no compilation
Termination
End Compilation
C:\TEMP >
```

In the above screen, the file EXAMPLE1 is entered at the first **source file** prompt. Esc is pressed at the second **source file** prompt, in order to return to *DOS*.

If, from your TEMP directory, you enter

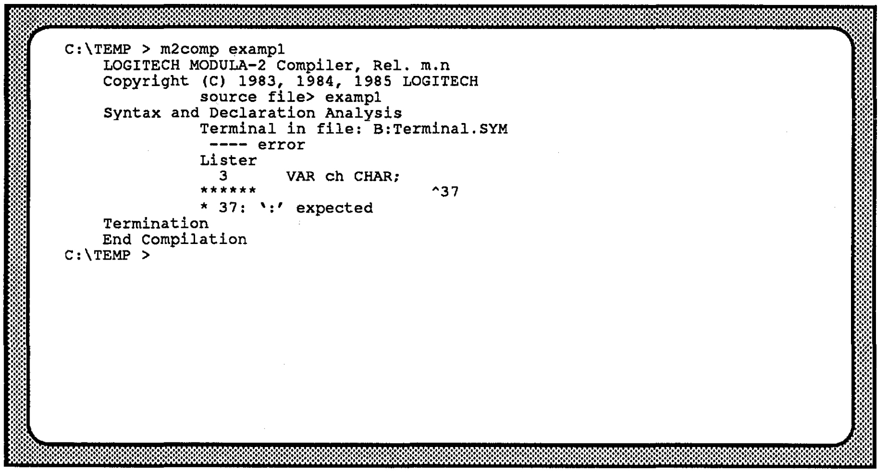
M2COMP ↵

you will see a screen that resembles the one below. As with the screen just discussed, if you press Esc at the **`source file`** prompt, you will be returned to the *DOS* prompt.



```
C:\TEMP > m2comp
LOGITECH Modula-2 Compiler, Rel. m.n
    Copyright (C) 1983, 1984, 1985, 1987 LOGITECH
    source file> Esc
    ---- no compilation
Termination
End Compilation
C:\TEMP >
```

`Syntax and Declaration Analysis`, `Block Analysis`, and `Code Generation` denote the succession of activated compiler passes. If errors are detected by the compiler, compilation stops after the pass that finds the error. Errors are displayed on the screen, and a listing file is generated with error messages similar to those below.



```
C:\TEMP > m2comp exampl
    LOGITECH MODULA-2 Compiler, Rel. m.n
    Copyright (C) 1983, 1984, 1985 LOGITECH
              source file> exampl
    Syntax and Declaration Analysis
              Terminal in file: B:Terminal.SYM
               ---- error
              Lister
                3      VAR ch CHAR;
              ******                      ^37
              * 37: ':' expected
    Termination
    End Compilation
C:\TEMP >
```

When the error display is more than one page, the compiler will ask if you want to see more errors after each page.

[Esc] stops the error listing display.

Pressing any other key continues the error listing.

This is true unless the **/Batch** option is used, in which case the compiler will not ask for more errors.

In both cases, the compiler generates the .LST error listing.

3.5 Compilation of a Definition Module

Compilation of a definition (.DEF) module is similar to the compilation of a program module. However, when a definition module is successfully compiled, a symbol (.SYM) file is the result; when a program or implementation module is compiled the result is a linkable object (.OBJ) file.

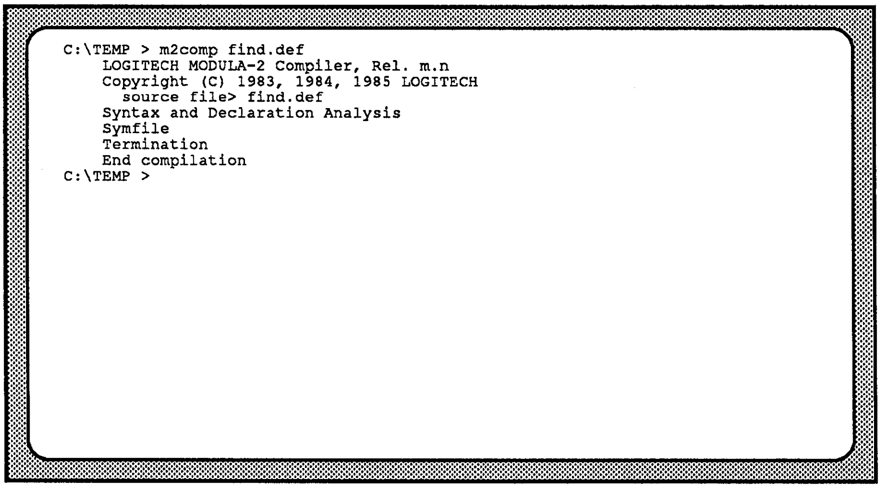
The symbol file contains the declarations of the definition part in symbolic, compiler-readable format. It also contains a unique module key which is used to check consistency. If errors are detected by the compiler, then a listing file is generated instead of the symbol file.

NOTE

A Definition Module must be compiled before its Implementation Module.

A Definition Module must be compiled before any module that imports it.

Example:



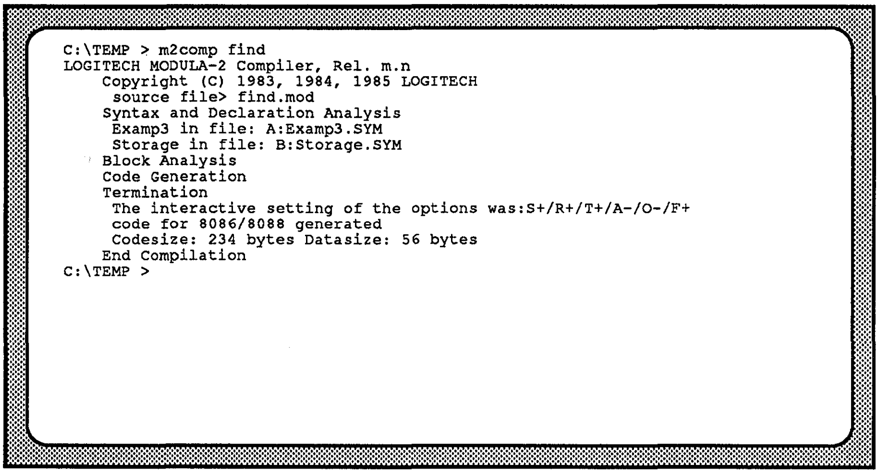
```
C:\TEMP > m2comp find.def
    LOGITECH MODULA-2 Compiler, Rel. m.n
    Copyright (C) 1983, 1984, 1985 LOGITECH
      source file> find.def
    Syntax and Declaration Analysis
    Symfile
    Termination
    End compilation
C:\TEMP >
```

3.6 Compilation of an Implementation Module

Compiling an implementation module is similar to compiling a program module.

When an implementation module is compiled, a symbol file for this module is needed. This symbol file is produced before compiling the implementation module, by compiling the corresponding definition module.

Compiler output files for implementation modules are the same as those generated when compiling a program module. A linkable object (.OBJ) file and a debug reference (.REF) file are generated as the result of a successful compilation. A listing file is produced only if there are errors.



```
C:\TEMP > m2comp find
LOGITECH MODULA-2 Compiler, Rel. m.n
    Copyright (C) 1983, 1984, 1985 LOGITECH
     source file> find.mod
    Syntax and Declaration Analysis
     Examp3 in file: A:Examp3.SYM
     Storage in file: B:Storage.SYM
    Block Analysis
    Code Generation
    Termination
     The interactive setting of the options was:S+/R+/T+/A-/O-/F+
     code for 8086/8088 generated
     Codesize: 234 bytes Datasize: 56 bytes
    End Compilation
C:\TEMP >
```

3.7 Symbol Files Needed for Compilation

Symbol files are used by the compiler for full inter-module checking. When a definition module is compiled, it generates a symbol file containing symbol table information. When the corresponding implementation part is compiled (or when a "client" module is compiled which imports it) the appropriate symbol file is read.

By default, the compiler first searches for symbol files on the disk/directory containing the source file. It uses the module name (truncated if necessary) as the filename, and a extension of .SYM. If a symbol file is not found on the first search, additional searches on other drives or directories are done automatically. (See the section on library search strategy for a complete description).

If a symbol file is not found, the compiler issues a message and asks for the file. This can be prevented, using the Autoquery option (see compiler options described below). If the Query option is turned on, the compiler will not perform any automatic searches. It will display the module name and let you enter the file name for every symbol file needed.

When the compiler asks for a symbol file, the request is repeated until an appropriate file is found or Esc is pressed. Esc tells the compiler that the file is not available. The compiler then stops at the end of the first pass, after listing all the required symbol files. This helps you detect any other missing files.

3.8 Compiler Options

When it reads the source file name, the compiler can also accept some options. Options are entered just after the filename, are preceded by a forward slash (/), and may use additional arguments (+) and (-). An option value is a predefined string that defines the state of the corresponding option. Possible values for the compiler options are listed below, followed by an explanation of their effects.

The default values in the following table are good unless you specify otherwise in a file which you can create named M2C.CFG. Keep this file in the M2EXE directory (where M2C.EXE resides) so it can be read by M2C.EXE or M2COMP.EXE. The default values M2C.CFG specifies will be applied to the filenames as if had been appended on the command line.

3.8.1 Table of Available Options

Option	Value for ON	Value for OFF	Default
query	Query	NOQuery	NOQ
autoquery	Aquery	NOAquery	A
interactive	Interactive	Batch	I
listing	Listing	NOListing	NOL
error listing	EListing	NOEListing	EL
emulator/coprocessor	Emulator	Coprocessor	E
8086/80286	2	8	8
version	Version	NOVersion	NOV
statistics	STATistics	NOSTATistics	STAT
stacktest	S+	S-	S+
float test	F+	F-	F+
rangetest	R+	R-	R+
indextest	T+	T-	T+
alignment	A+	A-	A-
optimize	O+	O-	O-
headerinlisting	Header	NOHeader	H
footerinlisting	Footer	NOFooter	NOF
dateinlisting	DAte	NODAte	NODA
debug	Debug	NODebug	D
symbol	SYmbol	NOSYmbol	SY
m2linker	M2L	NOM2L	M2L

To change the compile option defaults, put the desired settings (in the same syntax of the command line) into a file you create named M2C.CFG. In the above list, use either **Upper Case** letters (as in the bold letters in the table, above), or the complete name to specify an option. Optionally, **R**, **S**, **A**, **O**, and **T** may use the **+** argument.

3.8.2 Description of the Options

/Q
/NOQ **Query**
/A
/NOA **Autoquery**

Defines the search mechanism for the symbol files of imported modules. The following table shows the possible combinations of option settings and the corresponding behavior of the compiler:

Query	Autoquery	Action
Query	**A**query	Ask for filenames
Query	**NOA**query	Ask for filenames
NOQuery	**A**query	Search for file by default strategy. If not found, ask for filename.
NOQuery	**NOA**query	If not found, compile ends.

The default setting for these two options is /**NOQ**uery *and* /**A**query.

/I **Interactive**
/B **Batch**

Tells the compiler whether to run interactive or as a batch job. In interactive mode, display of error messages is stopped after a screen page and is resumed by hitting a key. This facility is turned off in the batch mode. Note: **Autoquery** is not affected by this option.

/L
/NOL **Listing**
/EL
/NOEL **Error Listing**

Says whether or not to generate a listing. This table shows how option combinations create corresponding behavior by the compiler.

Listing	EListing	A listing file is always generated.
Listing	NOEListing	Same as above.
NOListing	EListing	Detected errors generate a short error listing file with only the erroneous lines with error messages.
NOListing	NOEListing	No listing generated.

In all cases the compiler writes the lines with errors and the error message on the screen. Before each compilation, the compiler deletes the corresponding listing file (<filename>.LST).

/E **Emulator**
/C **Coprocessor**

This affects code generation for floating point arithmetic. If set to coprocessor, the compiler generates inline code for the **Intel 8087** numeric processor. Otherwise, it generates code for the ***LOGITECH REAL ARITHMETIC EMULATOR.***

/V
/NOV **Version**

The compiler displays information about the running version, for example, processor and operating system flags.

/STAT
/NOSTAT **Statistics**

At the end of a compilation the compiler displays statistics on the generated code.

/S+ /S-	**Stack test**
/R+ /R-	**Range and Overflow test**
/F+ /F-	**Float Arithmetic Error Test**
/T+ /T-	**Index and NIL pointer test**
/A+ /A-	**Alignment** Affects the variable and record field allocation. If set to **A+**, all variables except single bytes are allocated on even boundaries. If set to **A–**, no special effort is made to allocate variables on even boundaries. Choose either to save memory space **A–**, or increase program execution speed **A+**.
/O+ /O-	**Register Trace Optimization** Reduces code size and increases execution speed. (See the following subsection for more information.)
/8 /2	**8086** **80286** Affects code generation. If set to **8086**, the compiler generates code for the **8086/8088**. If set for **80286**, the compiler generates code for the **80186/80286**. The advanced instructions used are **ENTER, LEAVE, PUSH Immediate, Shift/Rotate Immediate,** and **Integer Immediate Multiply.**

/H /NOH	**Header in Listing**
/F /NOF	**Footer in Listing**
/DA /NODA	**Date in Listing**

These define the format of the generated listing file. The header option says whether a page header line is generated or not. The footer option defines whether a page footer line is generated or not. The date option says whether the date information is generated within the header line. The format of a page header line is:

```
MODULA-2      <filename.ext>            <date>            <page #>
```

Footer line text can only be defined in the compiler parameter module.

/D
/NOD **Debug**

This tells whether or not to generate the reference (.REF) file. This file contains the necessary information for the symbolic debugger.

/M2L
/NOM2L **LOGITECH Linker Information**

Instructs the compiler to produce extra information in the .OBJ file to allow the ***LOGITECH Linker*** to perform some improvements. The extra information lets the linker remove unreferenced procedure calls and constants from the .EXE file, and also allows the linker to search automatically for the files to be linked.

/SY
/NOSY **Symbol**

Produces symbol that will be used by debuggers. Refer to Appendix E for naming conventions if you don't use the ***LOGITECH Debugger***.

3.8.2.1 The Optimize Option

This option can be used to tighten code. This is done by tracking register content. Our test numbers show a reduction of up to 10% in size, and about the same increment in execution speed. The gain in speed and reduction in size may vary substantially from program to program. Compilation time is longer when optimization is ON (`/O+`).

To perform optimization on specific areas of source code (See Section 3.9), you can use `(*$O+*)`, `(*$O-*)`, and `(*$O=*)`.

When the compiler is instructed to use the optimize option, it considers that the program being compiled satisfies some requirements. The average ***Modula-2*** application usually meets these requirements but the programmer does have the ability to cheat the compiler.

In the following cases the requirement outline is sketched and some examples of bad and good program behaviour is given.

Case 1: Using ADR ( )

A memory update is not recognized to kill the previous value when the following conditions are true:

- Location type is any scalar type, and is designated either by a variable name or a record field name;
- A pointer is initialized with the address of that variable (via the ADR function);
- The location is updated before use by its name and then by the de-referenced pointer;
- This happens within an **EBB*** boundary.

This may lead to generation of bad code. To be safe, use in-line option `(*$O+/-*)`.

Example 1 shows where failing to put in-line options is an improper use of optimization.

Example 1

```
VAR p: POINTER TO INTEGER;
    i, j: INTEGER;
. . .
------------------> (*$O-*)
i   := something;
p   := ADR(i);
p^  := somethingElse;
j   := i;
------------------> (*$O+*)
. . .
```

* **EBB** or Extended Base Block. A code section that must be completely executed before the final statement in that section can be executed.

Case 2: Calling with VAR Parameter

The compiler doesn't perform inter-procedural alias analysis which sometimes leads to bad code, as follows:

Example 2

```
PROCEDURE P
  VAR i: INTEGER;
BEGIN
  . . .
  Q(i, i);
  . . .
END P;

PROCEDURE Q (VAR x, y: INTEGER);
  VAR a, b:: INTEGER;
BEGIN
    . . .
  ------------------> (*$O-*)
  x  := a;
  y  := a + 1;
  b  := x;
  ------------------> (*$O+*)
    . . .
END Q.
```

In procedure `Q`, variable `b` gets a bad value, since `x` and `y` are aliased to the same memory location. One way around this might be to use `(*$O-/+*)` to encapsulate the three statements in procedure `Q`.

Case 3: Safe Cases of Aliases

Cases of aliases other than those in Case 1 and Case 2, such as fields in a variant record (e.g., `p^` and `q^` when `p=q`, and `a[i]` and `a[j]` when `i=j`) are recognized by the compiler without your intervention.

Case 4: Using CODE Statement

Another situation that unsafely relates to the optimize option is playing tricks with the **CODE** statement. **CODE** statements are well treated by the compiler if they are "self-contained" — i.e., if they don't jump into the middle of another statement.

When the compiler encounters a **CODE** call, it resets all information about the content of the registers and resumes collecting at the next statement. This information can be faked by a misplaced jump. The examples illustrate the possible situations.

Example 3

```
. . .
CODE (073H,01H); (*              JNB @FOO          *)
CODE (040H);            (*              INC AX            *)
GETREG(AX, error);      (* @FOO:        MOV error,AX      *)
iF error THEN
. . .
```

The code in Example 3 above, is acceptable because after compilation of these statements, the registers descriptor will be properly initialized with the information that **AX** contains the variable "error".

Example 4

```
. . .
CODE (073H,04H); (*              JNB @FOO          *)
CODE (040H);            (*              INC AX            *)
GETREG(AX, error);      (*              MOV error, AX     *)
iF error THEN           (* @FOO:                          *)
. . .
```

The code in Example 4 above, is **not acceptable** because, after compilation, the register descriptor will be wrongly initialized with the information that **AX** contains the variable "error". This is not true if the **JNB** is taken.

This code style, even if accepted by the compiler, is not clean. It relies, for example, on the fact that the compiler will generate three bytes of code to translate the **GETREG** statement.

To repair the code in Example 4, either re-arrange the sequence, or use `(*$O-/+*)`.

3.9 Compiler Directives in Modules

Certain compiler directives may be specified in the source text of a module. These directives must appear immediately at the beginning of a comment and consist of $<letter><setting>, without any intervening or preceding spaces.

Letter	Definition	Default
S	Stack overflow test	S+
R	Subrange and arithmetic overflow test	R+
F	Real arithmetic error test	F+
T	Index test (arrays, case) and NIL pointer test	T+
A	Word alignment for variables and record fields	A–
O	Register Trace Alignment	O–

Setting	Effect
+	Set the option **ON**
-	Set the option **OFF**
=	Revert to setting before last

Example

```
MODULE x; (*$T+*)               test code is generated
...
(*$T-*)                         no test code is generated
CASE i OF
...
END
(*$T=*)                         test code is generated
...                             (i.e. the prior value is restored)
END x
```

3.10 Compiler Messages

There are two types of compilation errors:

- Errors detected in the source text printed on the listing and displayed on the screen.
- Operational errors displayed on the screen.

3.10.1 Source Text Errors

These errors appear in the listing file, marked under the offending line by a ^ and the error number. The source line and error message are also displayed on the screen as they are written to the listing. Compiler error messages are also listed in an appendix.

3.10.2 Compiler Operational Messages and Errors

Upon termination, the compiler sets the MS-DOS errorlevel system variable. This variable can be checked in a batch file. The generated values are:

0	successful compilation
1	abnormal termination due to internal errors
2	incomplete compilation due to missing files
3	source program error

During operation of the compiler the following messages and errors may be displayed:

```
Assertion of compiler
       internal reference: xx
       at source line : nn
Please send a bug-report to LOGITECH
```

We hope you never get this message. It is displayed when an internal consistency check of the compiler fails. If you get this message, please contact **LOGITECH** with a copy of the program which caused the error. The source line information may help you find a work-around. The internal reference is an indicator for the kind of problem that occurred and will help **LOGITECH** locate it.

`cannot load ...`

There is not enough memory to allocate all data areas the compiler needs or to load a compiler overlay. See the chapter on Program Execution for details.

`EOF on Control`

We hope this message never occurs. You see it when an internal consistency check of the lister fails. If you get this message, contact **LOGITECH** with a copy of the program that caused the error.

`error`

The compiler detected errors in your program. These errors will appear on the screen and in the listing file.

`error message first element on control`

See `EOF on Control`.

`file creation failed`

Your disk directory is probably full. When running under ***DOS***, this message may also appear if you did not boot your operating system from a disk that contains a CONFIG.SYS file, as described in the installation section of this manual.

`file not found`

A source or symbol file was not found. The compiler will repeatedly request the filename. You should either type the correct filename or press Esc if the required file is missing. When running under ***DOS***, this message may also appear if you did not boot your operating system from a disk that contains a CONFIG.SYS file, as described in the installation section of this manual.

`<file name> halted`

An overlay of the compiler terminated with an unexpected status. This might happen if you stop the compiler with Ctrl-Break or Ctrl-C.

`heap overflow`

There is not enough memory to allocate all data areas the compiler needs, or to load a compiler overlay. See the chapter on Program Execution for details.

`illegal option: <option typed>`

Please refer to the list of valid compiler options.

`Incorrect line number on Control`

See `EOF on Control`.

`incorrect module name`

The module name found in the symbol file does not correspond to the name of the module for which a symbol file is needed. Make sure you enter the right filename.

`NControl too small`

See `EOF on Control`.

`no compilation`

No compilation takes place because no source file was specified.

`no file`

You typed [Esc] when asked to enter a filename, and did not supply any file.

`not catalogued: <extension>`

The compiler had problems closing the file with the given extension. Make sure that the disks are in the drives.

`not deleted: <extension>`

The compiler had problems deleting the file with the given extension. Make sure that the disks are in the drives.

`output disk full`

Because of insufficient space on your disk, the compiler has stopped. You should delete superfluous files.

`<program name> program not found`

A compiler overlay was not found on the disk where it is expected to be. Please check whether you installed ***Modula-2*** properly. When running under DOS, this message may also appear if you did not boot your operating system from a disk that contains a CONFIG.SYS file, as described in the installation section of this manual.

`stack overflow`

Not enough memory to allocate all data areas the compiler needs or to load a compiler overlay.

`symbol files missing`

The compiler could not find all the symbol files for the imported modules. Therefore type checking is impossible and compilation stops. Check that the corresponding definition modules have been compiled and that all necessary symbol files have been specified correctly.

`<file name> warned`

An overlay of the compiler terminated with an unexpected status. This might happen if you stop the compiler with Ctrl-Break or Ctrl-C.

`wrong symbol file`

The file found is not a correct symbol file. Most likely, the file isn't a symbol file at all, or it was not generated by the same compiler.

3.11 Compiler Table Limits

The following error messages depend on some internal compiler table sizes. The following list gives the description of the errors and the actual table size of the compiler:

`7 too many identifiers (identifier table full)`

Identifier table holds 30,000 characters. This is the limit on the total number of characters of all distinct identifiers in one module and the exported identifiers of its imported modules.

Contrary to readable, self-documenting programming style, *shorter identifiers* and use of *the same identifiers in different scopes* helps avoid this message.

`8 too many identifiers (hash table full)`

Hash table holds 3571 identifiers. This limits the number of distinct identifiers in one module, including all the identifiers exported by the imported modules.

The same identifier names in different scopes helps avoid this message.

`205 implementation restriction: procedure too long`

Code size per procedure limited to 5000. Split the procedure into smaller entities.

`206 implementation restriction: statement table overflow`

Number of statements per procedure limited to 1000. Split the procedure into smaller entities.

`209 expression too complicated: jump table overflow`

Jump table size is 50 entries. This determines the number of possible short circuit jumps in a boolean expression.

Try breaking the expression into several temporary expressions.

`210 too many globals, externals, and calls (linker table overflow)`

The linker table holds fixup information for the linker. The size of this table is 850 entries per procedure. Access to an imported variable generates one entry; a call to an imported procedure generates two entries. A forward call to a local procedure generates one entry.

Split the procedure into smaller sections, or reduce frequency of access to imported variables and calls to imported procedures.

3.12 Compiler Error Messages

0:	illegal character in source file
1:	
2:	constant out of range
3:	open comment at end of file
4:	string terminator not on this line
5:	too many errors
6:	string too long
7:	too many identifiers (identifier table full)
8:	too many identifiers (hash table full)
20:	identifier expected
21:	integer constant expected
22:	']' expected
23:	';' expected
24:	block name at the END does not match
25:	error in block
26:	':=' expected
27:	error in expression
28:	THEN expected
29:	error in LOOP statement
30:	constant must not be CARDINAL
31:	error in REPEAT statement
32:	UNTIL expected
33:	error in WHILE statement
34:	DO expected
35:	error in CASE statement
36:	OF expected
37:	':' expected
38:	BEGIN expected
39:	error in WITH statement
40:	END expected
41:	')' expected
42:	error in constant
43:	'=' expected
44:	error in TYPE declaration

45:	'(' expected
46:	MODULE expected
47:	QUALIFIED expected
48:	error in factor
49:	error in simple type
50:	',' expected
51:	error in formal type
52:	error in statement sequence
53:	'.' expected
54:	export at global level not allowed
55:	body in definition module not allowed
56:	TO expected
57:	nested module in definition module not allowed
58:	'}' expected
59:	'..' expected
60:	error in FOR statement
61:	IMPORT expected
70:	identifier specified twice in importlist
71:	identifier not exported from qualifying module
72:	identifier declared twice or illegal forward reference to this identifier
73:	identifier not declared
74:	type not declared
75:	identifier already declared in module environment
76:	
77:	too many nesting levels
78:	value of absolute address must be of type CARDINAL
79:	scope table overflow in compiler
80:	illegal priority
81:	definition module belonging to implementation not found
82:	structure not allowed for implementation of hidden type
83:	procedure implementation different from definition
84:	not all defined procedures or hidden types implemented
85:	name conflict of exported object or enumeration constant in environment
86:	incompatible versions of symbolic modules
87:	

88:	function type is not scalar or basic type
89:	
90:	pointer-referenced type not declared
91:	tagfieldtype expected
92:	incompatible type of variant-constant
93:	constant used twice
94:	arithmetic error in evaluation of constant expression
95:	incorrect range
96:	range only with scalar type
97:	type-incompatible constructor element
98:	element value out of bounds
99:	set-type identifier expected
100:	structured type too large
101:	undeclared identifier in export list of the module
102:	range not belonging to base type
103:	wrong class of identifier
104:	no such module name found
105:	module name expected
106:	
107:	set too large
108:	
109:	scalar or subrange type expected
110:	case label out of bounds
111:	illegal export from program module
112:	code block for modules not allowed
119:	illegal variable as FOR loop counter
120:	incompatible types in conversion
121:	this type is not expected
122:	variable expected
123:	incorrect constant
124:	no procedure found for substitution
125:	unsatisfying parameters of substituted procedure
126:	set constant out of range
127:	error in standard procedure parameters
128:	type incompatibility
129:	type identifier expected

130:	type impossible to index
131:	field not belonging to a record variable
132:	too many parameters
133:	function parenthesis missing
134:	reference not to a variable
135:	illegal parameter substitution
136:	constant expected
137:	expected parameters
138:	BOOLEAN type expected
139:	scalar types expected
140:	operation with incompatible type
141:	only global procedure or function allowed in expression
142:	incompatible element type
143:	type incompatible operands
144:	no selectors allowed for procedures
145:	only function call allowed in expression
146:	arrow not belonging to a pointer variable
147:	standard function or procedure must not be assigned
148:	constant not allowed as variant
149:	SET type expected
150:	illegal substitution to WORD or BYTE parameter
151:	EXIT only in LOOP
152:	RETURN only in PROCEDURE
153:	expression expected
154:	expression not allowed
155:	type of function expected
156:	integer constant expected
157:	procedure call expected
158:	identifier not exported from qualifying module
159:	code buffer overflow
160:	illegal value for code
161:	call of procedure with lower priority not allowed
170:	global data too large (more than 64K bytes)
171:	local data too large (more than 32K bytes)
172:	parameter data too large (more than 32K bytes)

200:	compiler error
201:	implementation restriction
202:	implementation restriction: FOR step too large
203:	implementation restriction: boolean expression too long
204:	implementation restriction: expression too complicated
205:	implementation restriction: procedure too long
206:	implementation restriction: statement table overflow
207:	implementation restriction: illegal type conversion
208:	
209:	expression too complicated: jump table overflow
210:	too many globals, externals and calls (linker table overflow)
211:	implementation restriction: code >= 64K bytes
220:	not further specified error
221:	division by zero
222:	index out of range or conversion error
223:	case label defined twice
224:	DEFINITION expected

Chapter 4
Linking Modula-2 Files

The .OBJ files you obtain after the compilation can be linked by the ***LOGITECH Linker*** or with the linker that comes with your version of ***DOS***.

The ***LOGITECH Linker*** is part of the ***LOGITECH Modula-2 Toolkit*** and runs either from the ***DOS*** command line or from the **M2ASSIST** extension of the ***POINT*** Environment. The ***LOGITECH Linker*** supports a multi-layer overlay scheme, is able to link by procedure rather than by module (this will make your executable files smaller), and is able to find all the needed files automatically.

Please refer to the manual for the linker you will be using for details on its use.

Caution

The ***DOS*** Linker is not case-sensitive.

Thus: if you have two symbols that differ only in case, the ***DOS*** Linker displays

```
Symbol defined twice
```

One solution to this problem is to use the **/NOSYMBOL** compiler option, which defines fewer symbols.

Another solution is to use a linker that recognizes the **/NOIGNORECASE** option

Note: your object files may not link with ***DOS Linkers*** older than version 2.30.

Notes:

Chapter 5
Version Checking

All modules in a program must be compiled with consistent versions of module definitions.

When you change a module definition .DEF file, you must also recompile all program and implementation modules using that module before you can create a new executable program. When you compile a changed .DEF file, this creates a new .SYM file which is incompatible with any other version of that module. Even if you don't change anything in the definition part, recompiling it creates a new version of the .SYM file.

5.1 Module Keys and Version Checking

LOGITECH Modula-2 checks for version consistency and keeps inconsistent versions from being compiled together.

Version checking is simple in concept, but can be complex in application. Each time you recompile a .DEF file it creates a different module key for the resulting .SYM file.

Once you compile a .DEF definition file, you can compile its "client" implementation module which uses the definition part. These other modules will import the module, and the compiler will find the compiled version of the definition part, and use it to fully check the module being compiled. The module key of the referenced definition parts are in the compiled output.

At compile, link and load time, *LOGITECH Modula-2* verifies that all the keys included for a given definition module are the same. This guarantees that all modules which share an interface are compiled with the same version of the interface. This ensures the consistency of the program, as if there was only one source file, compiled all at once.

5.2 Version Errors and How to Fix Them

If the version consistency rule is broken, you will get a version error during either compilation, linking, or (sub)program loading. The following sections describe the typical cause and some possible corrections for version errors.

NOTE

The *M2MAKE* utility from the *LOGITECH Modula-2* Toolkit is the easiest way to resolve version errors.

5.3 Version Errors During Compilation

A version error while compiling module A.MOD can only arise if there is some definition module X.DEF that is imported by two different paths into A.MOD, and the version imported by one path is not the same as the version imported on the other path.

Look for a moment at the following example:

A.MOD	imports	B.DEF and C.DEF
B.DEF	imports	X.DEF
C.DEF	imports	X.DEF

Suppose that we compile as follows:

X.DEF	becomes	X.SYM (version 1)
B.DEF	becomes	B.SYM (uses version 1 of X)
X.DEF	becomes	X.SYM (version 2)
C.DEF	becomes	C.SYM (version 2 of X)
A.MOD	becomes	A.OBJ

There will be a version error when A.MOD is compiled, because the version of X.DEF imported through B.DEF is not the same as the version imported through C.DEF. The recompilation of X.DEF is the source of the version conflict. Before A.MOD can be compiled, B.DEF must be recompiled with the newer version of X.DEF.

5.4 Version Errors During Linking

When two or more modules are linked together, a version error can occur if some definition module has been used in two different versions by the linked modules.

Example:

MAIN.MOD	imports	InOut, Terminal.
INOUT.DEF	defines	InOut
	imports	nothing.
INOUT.MOD	implements	InOut
	imports	Terminal.
TERMINAL.DEF	defines	Terminal
	imports	nothing.
TERMINAL.MOD	implements	Terminal
	imports	nothing.

Then suppose these compilations are done:

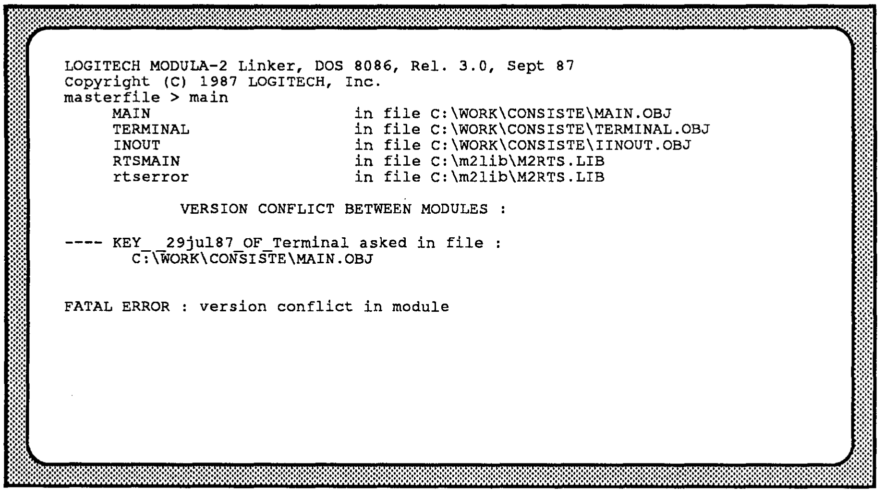
From	**To**	
TERMINAL.DEF	TERMINAL.SYM	(version 1)
INOUT.DEF	INOUT.SYM	
INOUT.MOD	INOUT.OBJ	(uses version 1 of Terminal)
TERMINAL.MOD	TERMINAL.OBJ	(corresponds to version 1)
TERMINAL.DEF	TERMINAL.SYM	(version 2)
MAIN.MOD	MAIN.OBJ	(uses version 2 of Terminal)

Under these conditions, linking MAIN.MOD generates a version conflict between the version of TERMINAL.SYM used by MAIN.MOD, and the version used by TERMINAL.MOD and INOUT.MOD. One solution is to recompile INOUT.MOD and TERMINAL.MOD with the new TERMINAL.SYM and link again.

The version conflict will be shown by the linker as an unresolved public symbol withthe following format:

KEY__DDMMMYY_HHMM_OF_<moduleName>

where **YY** is for the last two digits of the year, **MMM** for the first three letters of the month, **DD** for the two digits of the day of the month, **HH** for the two digits for the hour, and **MM**, the two digits for the minutes.



```
LOGITECH MODULA-2 Linker, DOS 8086, Rel. 3.0, Sept 87
Copyright (C) 1987 LOGITECH, Inc.
masterfile > main
     MAIN                         in file C:\WORK\CONSISTE\MAIN.OBJ
     TERMINAL                     in file C:\WORK\CONSISTE\TERMINAL.OBJ
     INOUT                        in file C:\WORK\CONSISTE\IINOUT.OBJ
     RTSMAIN                      in file C:\m2lib\M2RTS.LIB
     rtserror                     in file C:\m2lib\M2RTS.LIB

            VERSION CONFLICT BETWEEN MODULES :

---- KEY__29jul87_OF_Terminal asked in file :
       C:\WORK\CONSISTE\MAIN.OBJ

FATAL ERROR : version conflict in module
```

Figure 5-1: Sample of Version conflict at link time

5.5 Version Errors During Loading

When the ***LOGITECH Modula-2*** *Overlay schema* (which is only accessible through the ***LOGITECH Linker***) is used to build an application program, an additional check is made by the ***LOGITECH Modula-2*** system. The system can detect inconsistency at load time between the base and overlay layers. This error will happen when an incorrect version of the .MAP fiel is used when the overlay is linked. Here is a typical case:

A base layer is compiled and linked to produce MYPROG.EXE and MYPROG.MAP. Next, a version of MYOVL1.OVL is produced, using MYPROG.MAP as the base .MAP file.

Later, some modules of MYPROG.EXE are changed and the base layer is recompiled and relinked. This generates **a second version** of MYPROG.MAP that is **different from the first version** of MYPROG.MAP that was used to generate MYOVL1.OVL.

The difference in .MAP versions will be flagged at run time as inconsistant.

Remedy this situation by relinking the overlay programs with the new .MAP file version.

Chapter 6 Interfacing Other Languages

LOGITECH Modula-2 uses the standard .OBJ object file format of *DOS*. This means you can link *LOGITECH Modula-2 Compiler* output files with .OBJ object files produced by other compilers or by the assembler.

You need three pieces of information for an interface between different languages:

- Precise symbol names in the .OBJ file as procedure entrypoint and variables: *C* puts an _ (underscore) before symbols; other languages put symbols in upper case.
- Calling conventions:
  When one procedure calls another, parameter information is passed between them. Each type of information is put on the stack in an order that is dependent on the language and its implementation. A function also returns information into registers.
- How the run-time supports of the different languages interact.

LOGITECH Modula-2 gives you three ways to handle this interface.

- You can follow the *LOGITECH Modula-2* conventions described in Appendix B.9, B.10, and B.11. Section 6.1 shows you how to write such an *Assembly* program. If the procedure to be called is in a high-level language, create an *Assembly* interface.
- You can use *Modula-2* low-level features like EXTCALL, CODE, SEGREG, GETREG in order to follow the convention of the external procedure that you call. See Section 6.2.
- *LOGITECH Modula-2* has an extension which helps you interface other languages by defining foreign definition modules. This is described in Section 6.3.

6.1 Assembly Implementation with Modula-2 Conventions

This section describes the *Assembly* language routine in Figure 6-1, which can be called by a *LOGITECH Modula-2* program. This routine in turn calls the **Write** procedure from the **Terminal** module of the standard *Modula-2* library.

Follow these steps:

Step 1: Write a Modula-2 Definition File.

This .DEF file will reference the names of your *Assembly* language procedures, variables, and their structures for the *Modula-2* program listed in Figure 6-2.

Step 2: Compile the .DEF file.

This will create a .SYM file.

Step 3: Write an Assembly Language Program.

See the sample listing in Figure 6-1. You need to define an initialization routine which will be executed before the main part of your program is run. In *Modula-2*, each module which is imported must be initialised before being used.

Since *Modula-2* performs version checking, your *Assembly* program must define a public symbol with information about your .DEF file. This is called the key; it contains the date of the .SYM file you created at Step 2.

The key is defined as:

```
KEY__ <date of SYMfile> _OF_ <module name>
```

`KEY__` uses two underline characters with no break;
`<date of SYMfile>` uses the case-sensitive format `ddmmmyyy_hhmm` where;
`dd` stands for the day;
`mmm`, the month;
`yy`, the year;
"_" is a separator;
`hh` stands for the hour; and
`mm` stands for the minute.

When compiling a *Modula-2* implementation module, the compiler generates this key, and at the same time, makes sure that your implementation corresponds to your definition. As you write in *Assembly*, remember: an automatic check cannot be performed to insure that your *Assembly* code follows the definition; that is your responsibility!

Step 4: Assemble the .ASM File.

Use an assembler to produce a .OBJ file. Remember that ***Modula-2*** is case sensitive, so use this option in your assembler.

Step 5: Link the different .OBJ Files.

If you use a ***DOS*** linker, include the names of all the necessary .OBJ files on the command line, including the file you created with the assembler.

With the ***LOGITECH Linker***, you don't need to specify all the filenames: the name of the main program file is enough. If your ***Assembly*** program imports a file not in the standard library, then you must specify that file on the command line when you link.

Step 6: Run the .EXE file.

The .EXE file produced by the linking can be run like any other .EXE file.

This sample program shows the interface between *Assembly* and ***LOGITECH Modula-2***

- The initialization procedure writes "**hello**"
- The main module calls the **AsmWrite** procedure to write a string; this procedure uses the procedure **Write** in the **Terminal** module of the standard library.

Figure 6-1: EXASM Program Listing.

```
               TITLE   ExAsm
;
;              The symbol  KEY_ _<dateSYMfile>_OF_<modulename> is needed for version
;              checking of Modula-2.  Its value has no special meaning, usually 0.

               PUBLIC KEY_ _19jun87_2007_OF_ExAsm
KEY_19jun87_2007_OF_ExAsm EQU 0
;
;              Exported Procedures
               PUBLIC  L_ _AsmWrite_ExAsm
;
;              Initialization entrypoint
               PUBLIC  $INIT_ _ExAsm
;
;              Exported Variables
               PUBLIC  text_ _ExAsm
;
;              Used procedures
               EXTRN   L_ _Write_ _Terminal: FAR
               EXTRN   $INIT_ _Terminal: FAR
;
ExAsm_TEXT     SEGMENT BYTE PUBLIC 'CODE'
               ASSUME  CS : ExAsm_TEXT

;---------------------------------------------------------------------------------
L_ _AsmWrite_ _ExAsm  PROC  FAR
;---------------------------------------------------------------------------------
;       Asmwrite( VAR str : ARRAY OF CHAR )
                 PUSH  BP                    ; save BP and SP
                 MOV   BP, SP                ; BP should not be changed -
                                             ; It will be used to access the parameters

                 MOV   AX, SEG ExAsm_DATA
                 MOV   DS, AX

                 ASSUME  DS : ExAsm_DATA
;         i:=0;
                 MOV   AX,0
                 MOV   i,AX
;         WHILE (i<=HIGH(str)) AND (str[i]<>0c)
while:           MOV   AX,i
                 CMP   AX, 10[BP]              ; HIGH(str) is offset at 10
                 JNBE  end
                 LES   BX,6[BP]                ; ADR(str)  is offset at  6
```

Figure 6-1: EXASM Program Listing (cont'd)

```
                 MOV   SI,AX
                 MOV   AL,ES:[BX+SI]
                 CMP   AL,0
                 JE    end
;           Write(str[i]);
                 PUSH  AX
                 CALL  L__Write__Terminal
;           INC(i);
                 MOV   CX, SEG ExAsm_DATA
                 MOV   DS, CX
                 INC   i
                 JMP   while
;
end:             MOV   SP,BP              ; restore SP and BP
                 POP   BP
                 RET   6                  ; release the 6 bytes
                                          ;   of the parameters
L__AsmWrite__ExAsm  ENDP
;
;---------------------------------------------------------------------------------
$INIT__ExAsm   PROC  FAR
;---------------------------------------------------------------------------------
               MOV   AX, INIT_FLAG_DATA           ; Test if already
               MOV   DS, AX                       ; initialized
               ASSUME    DS: INIT_FLAG_DATA
               MOV   AL, 1                        ; TRUE
               XCHG  AL, BYTE PTR FLAG_ExAsm
               OR    AL, AL                       ; is it FALSE or TRUE ?
               JNE   End_init                     ; skip if TRUE

; Execution of the init code -- here, for example, we write 'Hello'
; after initialization of all needed (imported) modules

                CALL  $INIT__Terminal
                MOV   AX, 7
                PUSH  AX
                MOV   AX,SEG ExAsm_DATA
                PUSH  AX
                MOV   AX,OFFSET text__ExAsm
                PUSH  AX
                CALL  L__AsmWrite__ExAsm
End_init:
                RET
$INIT__ExAsm   ENDP

ExAsm_TEXT      ENDS

INIT_FLAG_DATA SEGMENT WORD PUBLIC 'FAR_DATA'
FLAG_ExAsm      DB      0                   ; initialization flag
INIT_FLAG_DATA ENDS

ExAsm_DATA      SEGMENT WORD PUBLIC 'FAR_DATA'
text__ExAsm     DB      ' Hello    '
i               DW      0
ExAsm_DATA      ENDS
             END
```

Figure 6-1: EXASM Program Listing (End)

```
DEFINITION MODULE ExAsm;
PROCEDURE AsmWrite (VAR str : ARRAY OF CHAR);
END ExAsm.
```

Figure 6-2: Modula-2 listing for EXASM.DEF

```
MODULE CallAsm;
FROM ExAsm IMPORT AsmWrite;
Var str : ARRAY [0..5];
BEGIN
   str := "folks!";
   AsmWrite(str);
END CallAsm;
```

Figure 6-3: Modula-2 listing for CALLASM.MOD

6.2 Use of Low-Level Features

The listing in Figure 6-4 tells how to call other high level languages, in this case a *C* library output routine.

LOGITECH Modula-2 **low level EXTCALL, CODE, SETREG, and GETREG features.**

```
MODULE Example;
FROM SYSTEM IMPORT EXTCALL, CODE, AX;
PROCEDURE CWrite(text: ARRAY OF CHAR);
BEGIN
   FOR i:=0 TO HIGH(text) DO
      SETREG(AX,text[i]);
      CODE(050H);     (* PUSH AX *)
         (* we call the C library routine _putchar *)
      EXTCALL    ("_putchar");
      CODE(058H);     (* POP AX *)
         (* caller must POP parameters after the call in C *)
   END;
END CWrite;
END Example.
```

Figure 6-4: ***LOGITECH Modula-2*** low level EXTCALL, CODE, SETREG, and GETREG

WARNING

In this method, nothing is done to initialize *C* run-time support. This means that you cannot use the *C* routines which depend on run-time support.

6.3 Foreign Definition

The ***LOGITECH Modula-2 Development System*** lets you declare foreign definition modules that interface other languages. These modules have the same syntax than the standard Modula-2 definition modules except that they should begin with the keyword **FOREIGN** which may be followed by a qualifier indicating the language to interface:

ForeignDefinitionModule = FOREIGN [LanguageQualifier] DefinitionModule
LanguageQualifier = C

A foreign definition module could look like this:

```
FOREIGN DEFINITION MODULE ForeignModule;
EXPORT QUALIFIED ForeignProc;
PROCEDURE ForeignProc ( num : INTEGER );
END ForeignModule.
```

Figure 6-5 Foreign Definition Module with no Qualifier

or like this:

```
FOREIGN C DEFINITION MODULE ForeignModule;
EXPORT QUALIFIED ForeignProc;
PROCEDURE ForeignProc ( num : INTEGER );
END ForeignModule.
```

Figure 6-6 Foreign Definition Module with C Qualifier

6.3.1 Conventions Used

The implementation of the foreign definition module can be in any language whose compiler generates the standard .OBJ file format, and uses both the symbol name and the parameter passing conventions explained below.

6.3.1.1 Symbol Name Convention

If you don't use any language qualifier, the compiler will assume that the symbol names generated by the foreign compiler are the very same symbol names as those declared in the foreign definition module. This is convenient when interfacing *Assembly* language because the symbol names generated by the assembler in the .OBJ file are the same as those in the source code. *Pascal* compilers usually generate the samne symbol names too in the .OBJ file, but all in upper case. (This is not a problem when linking with hte *DOS* linker, which is not case-sensitive.)

- In *Assembly* language, declare the symbols as described below:

```
ForeignProc PROC FAR       ; for a routine named ForeignProc in
...                        ; the foreign definition module.
ForeignProc ENDP
```

If you use the language qualifier "C" to indicate that the foreign language is *C* language, the compiler will assume that the routine symbol names are the very same as those declared in the foreign definition module, but that the data symbol names are the symbol names with a _ (underscore) at the very beginning of the name. *Microsoft C, version 4.0* automatically adds the underscore at the beginning of data names. For routine names, the keyword **`pascal`** should be used to indicate to the C compiler to generate the symbol name only.

- *Microsoft C, version 4.0*, declares the routine as described below :

```
far pascal ForeignProc ( num )
int num;
{
...
}
```

Data symbol names are automatically added with an underscore with *Microsoft C.*

You can implement the foreign module in *Modula-2* itself; the compiler assumes that this *Modula-2* module will be called by another language with the conventions described above. If you already have software written in another language, you can use *Modula-2* to develop additional, complementary code. The declaration of the routine should be as usual:

```
PROCEDURE ForeignProc ( num : INTEGER );
BEGIN
  ...
END ForeignProc;
```

6.3.1.2 Parameter Passing Convention

The parameters are passed with the ***Pascal*** convention : i.e., the parameters are pushed from left to right by the caller and the stack is cleared by the called routine before returning to the caller. Here are some examples :

- For the assembly language the parameters should be popped in the reverse order than they were pushed, and the stack should be cleared before the return. Please see the example below for interfacing with assembly language.
- When using ***Version 4.0*** of ***Microsoft C,*** the keyword `pascal` will indicate to the compiler to use the ***Pascal*** convention for passing the parameters.
- When using ***LOGITECH Modula-2*** to implement the foreign routine, the compiler will automatically use the ***Pascal*** convention for passing the parameters.

6.3.1.3 Default Data Segment When Using "C" Qualifier

To be compatible with ***Version 4.0*** of ***Microsoft C,*** the data segment should contain by default the segment of a group named DGROUP. Therefore before any call to a foreign module routine, the ***LOGITECH Modula-2*** compiler generates the following code sequence :

```
MOV AX, SEG DGROUP
MOV DS, AX
CALLF ForeignProc
```

6.3.2 Examples of Foreign Definition Modules

In the examples below the foreign definition module is one of the two above. The differences are whether the main program is in *Modula-2* or in another language. The details are discussed below.

6.3.2.1 "main" in Modula-2, and "foreign module" in C

The foreign definition module is the one in Figure 6-6, above.

Here is the *C* implementation of **ForeignProc**:

```
far pascal ForeignProc ( num )
int num;
{
int i;
   printf("This is C Language\n");
   for (i=0;i<num;i++)
       printf("Hello Folks ...\n");
}
```

The command for compiling this file is:

```
MSC /AL FOREIGNM.C ↵
```

Here is the main program in *Modula-2*:

```
MODULE MainMod;

FROM ForeignModule IMPORT ForeignProc;
FROM Terminal      IMPORT WriteString, WriteLn;

BEGIN
   WriteString("This is Modula-2");WriteLn;
   ForeignProc(10);
   WriteString("This is Modula-2");WriteLn;
END MainMod.
```

The command for compiling this file is:

```
M2C FOREIGNM.DEF MAINMOD.MOD ↵
```

The command for linking these files is:

```
LINK MAINMOD.OBJ+FOREIGNM.OBJ/MAP ↵
```

The screen interaction you see while linking looks like this:

```
Run File [MainMod.EXE]:
List File [MainMod.MAP]:
Libraries [.LIB]:\M2LIB\LIB\MCRTS.LIB+\M2LIB\LIB\M2LIB.LIB
Cannot find library: M2USER.LIB
Enter new file spec:
```

To initialize ***C run time support***, MCRTS.LIB should be used when linking. This library file does not ask for the entry point of the .EXE file. Therefore the entry point will be given to the ***C run time support*** which will, after its initialization, call **_main** — which is declared at the entry point of RTSMAIN.OBJ. After initialization of the ***Modula-2 RTS*** the main part of **MainMod** is called.

To run the program, simply type :

MAINMOD ↵

6.3.2.2 "main" in C and "foreign module" in Modula-2

The foreign definition module is the one in **Figure 6-6** above, with the "C" qualifier.

Here is the ***Modula-2*** implementation of **ForeignProc** :

```
IMPLEMENTATION MODULE ForeignModule;

FROM Terminal IMPORT WriteString, WriteLn;

PROCEDURE ForeignProc ( num : INTEGER);
VAR i : INTEGER;
BEGIN
   WriteString ("This is Modula-2");  WriteLn;
   FOR i := 1 TO num DO
      WriteString ("Hello Folks ..."); WriteLn
   END
END ForeignProc;

END ForeignModule.
```

The command for compiling this file is:

M2C FOREIGNM.DEF FOREIGNM ↵

Here is the main program in C.

```
far pascal ForeignProc ( int );

main ()
{
        printf("This is C Language\n");
        ForeignProc(10);
        printf("This is C Language\n");
}
```

The command for compiling this file is:

MSC /AL MAINC.C; ↵

Link these files with the following command:

LINK MAINC.OBJ+FOREIGNM.OBJ/MAP ↵

You should see the following output:

```
Run File [MainC.EXE]:
List File [MainC.MAP]:
Libraries [.LIB]:\M2LIB\LIB\CMRTS.LIB+\M2LIB\LIB\M2LIB.LIB
Cannot find library: M2USER.LIB
Enter new file spec:
```

To initialize ***C run time support*** and ***Modula-2 RTS***, use the CMRTS.LIB file when linking. CMRTS.LIB asks for the entry point of the EXE file. Therefore the ***Modula-2 RTS*** is initialized first, and then calls **`__astart`**, which is the entry point for ***C run time support***. After the ***C run time support*** is initialized, the call is done to **`_main`**.

To execute the program just type :

MAINC ↵

6.3.2.3 "main" in Modula-2 and "foreign module" in Assembly

The foreign definition module is shown in Figure 6-5 above, with no language qualifier.

Here is the ***Assembly*** implementation of **ForeignProc**:

```
TITLE ForeignModule

PUBLIC ForeignProc

ForeignModule_TEXT SEGMENT BYTE PUBLIC 'CODE'
ForeignModule_TEXT ENDS
ForeignModule_DATA SEGMENT WORD PUBLIC 'FAR_DATA'
ForeignModule_DATA ENDS

ASSUME CS: ForeignModule_TEXT,  DS: ForeignModule_DATA

ForeignModule_DATA SEGMENT
               str1  DB 'This is assembly language', 0AH, 0DH, '$'
               str2  DB 'Hello Folks ...',           0AH, 0DH, '$'
ForeignModule_DATA ENDS

ForeignModule_TEXT SEGMENT

ForeignProc    PROC FAR
               PUSH BP
               MOV BP, SP
               SUB SP, 2                             ; reserves 2 bytes
               MOV AX, SEG    ForeignModule_DATA
               MOV DS, AX
               MOV DX, OFFSET ForeignModule_DATA:str1
               MOV AH, 9
               INT 021H                              ; writes str1 to screen
               MOV WORD PTR [BP-2],0; counter := 0
               JMP forloop

forblock:      MOV DX, OFFSET ForeignModule_DATA:str2
               MOV AH, 9
               INT 021H                               ; writes str2 to screen

               INC WORD PTR [BP-2]                    ; increments counter

forloop:       MOV AX, [BP+6]                         ; parameter num
               CMP [BP-2], AX                         ; is counter = num ?
               jl  forblock

               MOV SP, BP
               POP BP
               RET 2

ForeignProc   ENDP

ForeignModule_TEXT ENDS
END
```

The main program in ***Modula-2*** is the same as that in Section 6.3.2.1.

The command for compiling this file should be:

```
M2C FOREIGNM.DEF MAINMOD.MOD ↵
```

The command for compiling this file should be:

```
MASM FOREIGNM.ASM ↵
```

The commands for compiling and linking these files should be:

```
LINK MAINMOD.OBJ+FOREIGNM.OBJ/MAP ↵
```

You should see the following output:

```
Run File [MainMod.EXE]:
List File [MainMod.MAP]:
Libraries [.LIB]:\M2LIB\LIB\M2RTS.LIB+\M2LIB\LIB\M2LIB.LIB
Cannot find library: M2USER.LIB
Enter new file spec:
```

Warning with Foreign Modules

When using foreign definition modules, take low level considerations of different compilers into account. Some run time supports reroute some system calls and trap some interrupts. Be aware of the potential for this kind of problem.

LOGITECH Modula-2 utilities are tailored to work with ***Modula-2*** code generated by the ***LOGITECH Modula-2 Compiler***, and may not work perfectly with code generated by other compilers.

Chapter 7
The Symbolic Post-Mortem Debugger

The ***LOGITECH Symbolic Post-Mortem Debugger***, known as the ***LOGITECH PMD***, or simply the ***PMD***, lets you inspect a crashed program to find out what went wrong with the program and where the problem occurred.

LOGITECH Modula-2 works with two complementary debuggers: the ***Symbolic Post-Mortem Debugger*** (referred to as the ***LOGITECH PMD***, or simply the ***PMD***) is described in this chapter. The ***Symbolic Run-Time Debugger*** which is called the ***LOGITECH RTD***, or simply the ***RTD***, is part of the ***LOGITECH Modula-2 Toolkit*** and is described there.

The PMD lets you symbolically analyze a program that terminated abnormally. Thus, you can determine what went wrong, anD where the problem occurred. To do this, a memory dump must have been created and written onto a file by ***LOGITECH Modula-2 Run-Time Support***. This memory dump, together with the .REF reference files generated by the compiler, are taken by the ***PMD***, and you are given symbolic information on the state of the program: the procedure call chain with the procedure names, the modules they come from, and the values of all data according to their types and structures.

A memory dump is created only if the module **DebugPMD** has been imported into at least one of the program or sub-program (overlay) modules. The memory dump is written into the file <filename>.PMD, where <filename> is the name of the program or overlay file that contains the process that has terminated abnormally. If a program or overlay file terminates abormally, without the **DebugPMD** module linked to it, the program is merely terminated with an appropriate message.

If a program terminates abnormally and unpredictably, insert calls to the **DebugPMD** library module and recompile your source code. Then, after linking, run the program again. Then, when your program crashes, the memory image is saved on disk in a dump file. The ***PMD*** lets you inspect this dump file symbolically: it displays the state of the program, using the corresponding module and procedure names. It also shows the names and values of variables according to their type structure.

LOGITECH Modula-2 creates <program_name>.PMD, a memory dump file, when:

- A run-time error occurs.
- A program calls the standard procedure **HALT**.
- A program calls the **Terminate** procedure, exported by the **RTSMain** module , with a parameter other than **Normal** or **Warning.**
- Ctrl-Break or Ctrl-C is pressed while a program that imports the **Break** module is running.

The structure and user interface of the ***RTD*** are the same as that of the ***PMD***. The ***RTD*** uses the same windows and screen layout as the ***PMD***. The ***RTD*** commands are a superset of the ***PMD*** commands. All commands of the ***PMD*** are also valid in the ***RTD***

7.1 LOGITECH PMD Files

The following files are on the diskette:

```
MDA.CFG
CGA.CFG
EGA.CFG
 DB.CFG
 DB.HLP
PMD.EXE
```

The file extensions stand for:

.CFG	Configuration file
.HLP	Help file
.EXE	Executable file

7.2 The PMD and Your Hardware

The *LOGITECH PMD* works on *IBM PC* and compatible computers. We recommend that you run the *PMD* with a mouse, although it is possible to work without one. If a mouse is used, it is important to have recent mouse drivers: ***LOGITECH, Release 3.20*** or higher, or ***Microsoft, Release 6.00*** or higher.

The *PMD* requires approximately 260K bytes of memory, not counting *DOS* or any other drivers you may have installed.

The *PMD* can work with a *MDA*, *CGA* or *EGA* video controller. With a *CGA* and *EGA* the windows can have colors. With an *EGA* controller, the *PMD* can have a screen with **43** lines.

7.3 How to Run the Post-Mortem Debugger

To run the *LOGITECH PMD*, type:

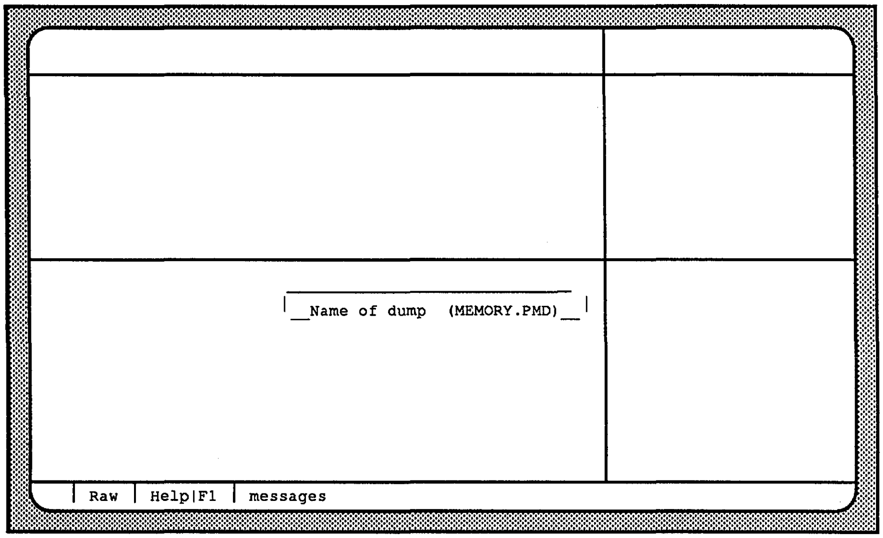
```
PMD    <dump_file_name_if_known>    ↵
```

The debugger responds with a sign-on message:

```
LOGITECH MODULA-2 Post-Mortem Debugger
```

followed by the version number and a copyright notice.

If you have not specified a dump file name, you will see the following screen. If you specified the name of the dump file on the command line you will not see the prompt.



```
Name of dump  (MEMORY.PMD)
```

Figure 7-1 Sample Screen

If you did not enter the dump file name on the command line, enter it here.

When the *PMD* is loaded, it executes some internal initialization, and then displays displays appropriate information in each window on the screen.

NOTE

If you use the dump file name on the command line specify it as an argument just after the debugger.

The *PMD* from *LOGITECH Modula-2, Version 3.0* uses the .MAP file of the program.

IMPORTANT !!!

! ! ! NO DEBUGGING CAN BE DONE WITHOUT A .MAP FILE ! ! !

The application program must be compiled with the SYMBOL option (which is set by default) and the link must be made with a .MAP file (default of the linker).

7.4 PMD Configuration

The *PMD* reads certain files during its initialization phase. One contains the layout of the screen, and one has information for the help window.

7.4.1 Screen configuration

The screen configuration is in the file DB.CFG. This file is a binary file which can not be edited. If the file is not found, the debugger prompts for it. If you press [Esc], you get the default setting for the screen. You can then modify the setting and either save it with the `save config` command, or be queried when you leave the debugger.

On the distribution disk, four screen configuration files are provided:

MDA.CFG	**Monochrome.** Fits all controllers. MDA.CFG is used when the configuration file is not found and you press [Esc].
CGA.CFG	**Color.** Works with *CGA* controller or with *EGA* in *CGA* mode.
EGA.CFG	**EGA .** Works in **43 lines mode**
DB.CFG	Same as MDA.CFG.

If the computer has an exotic display (e.g. **Olivetti, ATT,** or **COMPAQ**), start with MDA configuration (MDA is less critical).

7.4.2 On-line Help

On-line help is in a text file named DB.HLP. If DB.HLP is not found, you are not prompted for it.

NOTE

Search strategy is the same for both the *PMD* and *RTD*: the debugger first looks into the current directory and then in the directory from where it was loaded.

7.5 Post-Mortem Debugger Options

When you start the *PMD*, you may also specify various options on the command line. Options are denoted by a / (forward slash), followed by the first character of the option name. For example, to activate the **Query** option, enter:

PMD/Q ↵

when starting the *PMD*.

/Q

(default : **/Q-**)
Query

Tells the *PMD* to search for reference and source files according to the query search strategy. You will be prompted to enter the reference and source file names. If the Query option is not specified, the *PMD* automatically searches for these files according to the default search strategy.

7.6 User interface

7.6.1 Windows

The *PMD* uses windows for optimal viewing of executed code.

A window can be **open** or it can be an **icon**. Open windows show their contents. Icons appear as a labels on the last line of the screen. Throughout this chapter, we will often referred to a "window", meaning an open window, or to an "icon", which means a window label.

These windows cannot be overlapped and they always share the entire screen. A window is always displayed beside another window. For example, if the screen is divided vertically in two windows, a third window can be opened only at the border of one of the already opened windows.

There is always one active window. Therefor, if a menu is called it will referenc the functions in the active window. It is also possible to activate an icon so that its menu is available. The activation of the icon does not open it as a window.

The menus and the messages are displayed with pop-up windows.

Window functions are:

- Activate a window
- Scroll through the contents

- Change color screen colors:
  - Borders
  - Window Contents
  - Menus

- Change Size and Position:
- Move window borders (because they share the screen, the motion of a border modifies the size of adjacent windows)
  - Fill the whole screen (zoom window)
  - Shrink to become an icon
  - Swap position and/or size with another window. Can be swap an icon and a window, but not two icons.

All commands can be done with the mouse and/or with the keyboard. With the mouse, use the [■ ❑ ❑] double click which calls the most probable command, or use the menu. With the keyboard, use the menu or the short cuts. If the mouse is not connected, the mouse cursor is not displayed.

7.6.2 Mouse Functions

The mouse button is context sensitive. The table below describes these meanings.

Cursor position	■□□	□■□	□□■
Left Window Border	Scroll Up	Select Absolute Vertical Position	Scroll Down
Bottom Window Border	Scroll Left	Select Absolute Horizontal Position	Scroll Right
Bottom Left Corner of Window	Move Left Bottom Border	------	------
Inside Window	One Click: Select Double Click: Carry Out Most Probable Action On The Selection	Call Menu To Manipulate Window	Call Menu For Specific Window Actions
Prompt	Terminate User Entry	Escape from Prompt	Escape from Prompt
Menu	Execute Highlighted Action	Execute Highlighted Action	Execute Highlighted Action

Figure 7-2 Mouse Function Table

Note:

Scroll functions: Similar to those in the *POINT Editor* or *Microsoft Word.*

Attempting to scroll beyond the ends causes a beep.

If two-button mouse is used, use [■ ■] for [□ ■ □].

Click: [■ □ □] anywhere inside the window or on an icon you wish to select. [■ □ □] doesn't expand the icon, but gives you its local menu.

Move window borders: Select the lower left window corner (the other part of the border is used as scroll bar). If there is ambiguity, the *PMD* prompts you for a menu.

eXchange windows: Select one window. Then point at the other window with the mouse and select e**X**change in that window's menu. This moves the active window into the new window position.

The other window commands are available via the menu.

7.6.3 Keyboard Functions

7.6.3.1 How to scroll

The active window can be scrolled horizontally and vertically. The cursor keypad is mapped as follows for scrolling:

```
                              1 line up
                                  |
                                  |
                       +-------+-------+-------+
beginning              |       |       |       |
of text            --- | HOME  |   ^   | PG UP |---- 1 page up
                       |       |       |       |
                       +-------+-------+-------+
                       |       |       |       |
1 column        ------ |   <   |       |   >   |---- 1 column
to the left            |       |       |       |     to the right
                       +-------+-------+-------+
end of                 |       |       |       |
text           ------- |  END  |   V   | PG DN |---- 1 page down
                       |       |       |       |
                       +-------+-------+-------+
                                  |
                                  |
                              1 line down
```

[⇥] 1 page right

[⇑Shift]-[⇥] 1 page left

Figure 7-3 Cursor Key Scrolling

7.6.3.2 Select a window object

To select a window object, move cursor above the object and press [Spacebar] or [↵].

To activate a window, use a window activation command.

7.6.3.3 Call the menu

F10	Displays or erases the menu.
↵ or Spacebar	Validates the selected item in the menu.
Esc	Leaves the menu without performing the action.
Menu bar	Menu bar can be moved up or down. The cursor keypad is mapped as follows for bar moving:

```
                                        1 line up
                                            |
                                            |
                              +--------+--------+--------+
                              |        |        |        |
few columns           ---     | HOME   |   ^    | PG UP  |---- few lines up
to the left                   |        |        |        |
                              +--------+--------+--------+
                              |        |        |        |
1 column           ------     |   <    |        |   >    |---- 1 column
to the left                   |        |        |        |     to the right
                              +--------+--------+--------+
                              |        |        |        |
few columns           ---     |  END   |   V    | PG DN  |---- few lines down
to the right                  |        |        |        |
                              +--------+--------+--------+
                                            |
                                            |
                                       1 line down
```

Figure 7-4 Select The Menu Bar

However, it is faster to use keystroke commands. The menu beside the corresponding item displays the appropriate keystroke sequence.

◆ means Alt

^ means Ctrl

The musical note sign means ■ ❑ ❑ double click.

Off-menu, Esc purges the keyboard input buffer.

Wrong keystrokes are beeped, if beep is ON.

↵ and Spacebar activate the selected command.

7.6.3.4 Respond to a prompt

[↵] or [Spacebar]	Validates the characters entered to the debugger.
[Esc]	Aborts the input processing.
[Ctrl]-[X]	Erases all the input characters.
[← Back]	Erases the last character input.

NOTE

[■ □ □] acts as [↵].
[□ ■ □] and [□ □ ■] act as [Esc].

7.6.3.5 Move the mouse cursor with the keyboard

These functions are for the numeric keypad when a mouse is connected to the computer. You can move the mouse cursor by using [⇧Shift]- with the keypad. The cursor keypad is mapped as follows:

```
                                  1 line up
                                      :
                          +-------+-------+-------+
                          |       |       |       |
few columns           --- | HOME  |   ^   | PG UP |---- few lines up
to the left               |       |       |       |
                          +-------+-------+-------+
                          |       |       |       |
1 column           ------ |   <   |       |   >   |---- 1 column
to the left               |       |       |       |     to the right
                          +-------+-------+-------+
                          |       |       |       |
few columns           --- |  END  |   V   | PG DN |---- few lines down
to the right              |       |       |       |
                          +-------+-------+-------+
                                      :
                                  1 line down
```

Figure 7-5 Keyboard and Mouse

7.7 Windows and Commands

The *LOGITECH PMD* displays these windows:

Type	Function
`Call:`	Show the calling chain of your program at crash time
`Module:`	Show list of the modules in memory
`Text:`	*Modula-2* source file
`Data:`	Data defined in a module or procedure
`Raw:`	Direct access to the memory
`Help:`	Displays the contents of DB.HLP (help file)
`Message:`	Displays messages of the *PMD* (e.g., which file is accessed)

The *PMD* has two types of commands - global and local. Local commands are only applicable to the particular window in which they appear and are shown.

Quit command

This command lets you quit the *PMD*. If the screen layout was changed during the session and not saved, you can save the configuration at that time.

Window activation commands

You can switch from one window to another one by typing:

Keystrokes	Window Selected
[=] [C]	Call
[=] [M]	Module
[=] [D]	Data
[=] [T]	Text
[=] [R]	Raw
[=] [H]	Help
[=] [S]	meSsage

You can also click into the window or go through menu. When you activate an icon, it does not open it lets you use its menu. Open an icon with a window manipulation command.

[F1] opens the help window (full screen). [F1] exits the help window.

Window manipulation commands

You can move the window borders. With a mouse, the border can be selected by picking the lower left corner of a window (the other part of the border is used as scroll bar). If an ambiguity exists, the *PMD* prompts you for a menu to select. If no mouse is used, use Alt-M and the *PMD* prompts with a menu for the window to modify.

Alt-Z (Zoom) toggles a window between full and partial screen.

A window can be **open** or it can be an **icon**. A window is iconized (or shrunk Alt-S) when only its label is visible on the last line of the screen. You can open an icon with the vertical or the horizontal expand, Alt-V or Alt-H.

Alt-X, lets you exchange two windows. This command moves the active window in the selected window. Without a mouse, a menu lets you select the target window.

Configuration commands:

Alt-T	Bring up a menu to change screen colors:
	Alt-B, Alt-G — Border colors.
	Alt-L, Alt-O — Menu colors.
	Alt-C, Alt-D — Window content colors.
Alt-N	Turns a bell on or off.
Alt-F	Lets you save the configuration. If you do not save after a change, you will be prompted when you will leave the debugger.

Low level commands:

Alt-R	Redraws all windows.
Alt-P	Centers the current selection.

Menu commands:

F10	Invokes and exits the menu (toggle).

7.7.1 Call Window

The Call window displays the chain of procedure calls of the crashed process.

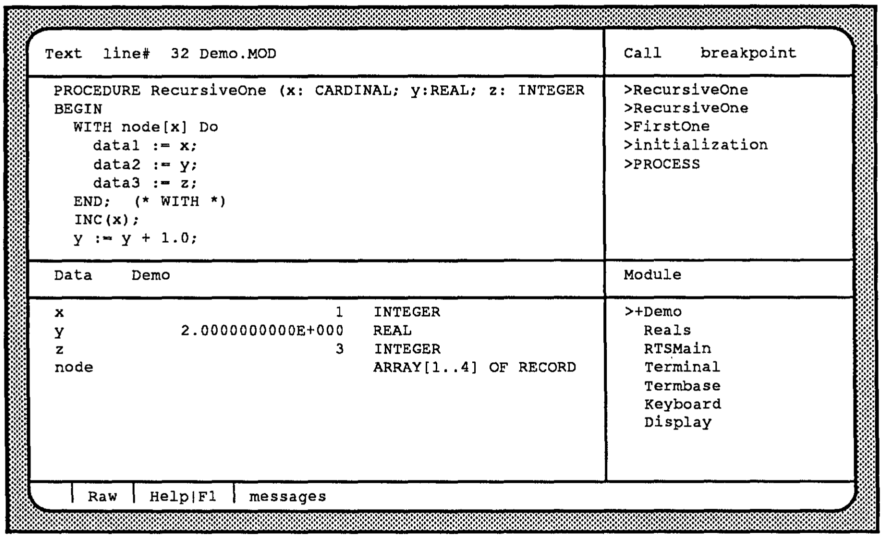
Local commands in the Call window:

Address:	Gives the address and line number of the executed statement.
Examine break process:	Updates all windows with the information related to the process running when the program stopped.
Data:	Updates the data window with the data of the selected element (**PROCEDURE** or **PROCESS**).
Text:	Updates the text window with the text of the selected element (**PROCEDURE** or **PROCESS**).
Both:	Executes Data and Text commands or is equivalent to the double click on the selected item.

NOTE

You can see the contents of the process only if RTSMAIN.REF is available.

The following screen shows the default setup of the windows.



```
Text  line#  32 Demo.MOD                                          Call    breakpoint

 PROCEDURE RecursiveOne (x: CARDINAL; y:REAL; z: INTEGER          >RecursiveOne
 BEGIN                                                            >RecursiveOne
   WITH node[x] Do                                                >FirstOne
     data1 := x;                                                  >initialization
     data2 := y;                                                  >PROCESS
     data3 := z;
   END;  (* WITH *)
   INC(x);
   y := y + 1.0;

 Data    Demo                                                     Module

 x                              1   INTEGER                       >+Demo
 y              2.0000000000E+000   REAL                            Reals
 z                              3   INTEGER                         RTSMain
 node                               ARRAY[1..4] OF RECORD           Terminal
                                                                    Termbase
                                                                    Keyboard
                                                                    Display

    | Raw | Help|F1 | messages
```

Figure 7-6 Sample Screen

7.7.2 Module Window

The Module window displays the list of modules of the program being debugged.

Local Commands in the Module Window

Find:	Lets you search for a module. Wildcard * and ? characters use the same syntax as ***DOS***. To select the next module name matching the input pattern use **Find** again and press [↵].
Address:	Gives data and code addresses of the module, and updates the raw window.
Data:	Updates the data window with data of the selected element.
Text:	Updates the text window with the text of the selected element.
Both:	Executes Data and Text commands or is equivalent to the double click on the selected item.

7.7.3 Data Window

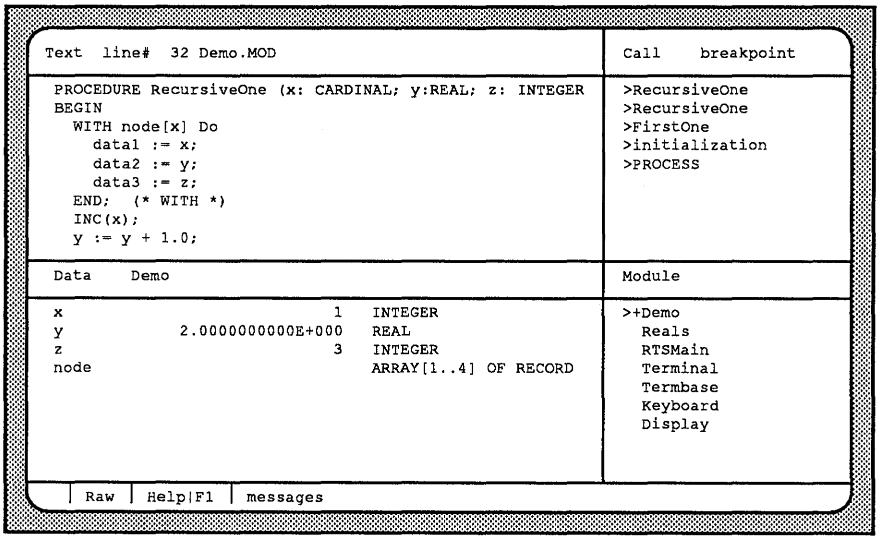
Data window displays variables and/or parameters of the selected procedure or module.

Local Commands in the Data Window

Son and Father:	Displays the data structure beneath the current level for the selected item. If the selected item is an array, the Son command displays the values of the elements of the array. If the selected variable is a record, the Son command displays the names and values of the record fields. Likewise, local modules are shown as data of the embedding module. You can also examine the content of the process descriptor by entering the Son command when a variable of type "**PROCESS**" is selected. In addition, this command can be used to follow linked lists when you select a variable which is a pointer or is of type "**ADDRESS**". The double click applies these functions. The command Son is applied when an element is "double clicked". The command Father is applied when the path on the top of the window is "double-clicked". The command Son can be used on a variable of type **PROCESS** only if the file RTSMAIN.REF is available.
eXchange:	Lets you switch from procedure local data to module global data and vice versa.
Right/Left:	These commands are only applicable when the selected data item is an element of an array, or part of an element of an array. The Right and Left commands select the element with the next higher or lower index in the array. The current level is not changed by these commands. If the array elements are records, the record field selected is not affected.
Index:	Lets you select randomly an element of an array by giving the value of its index.

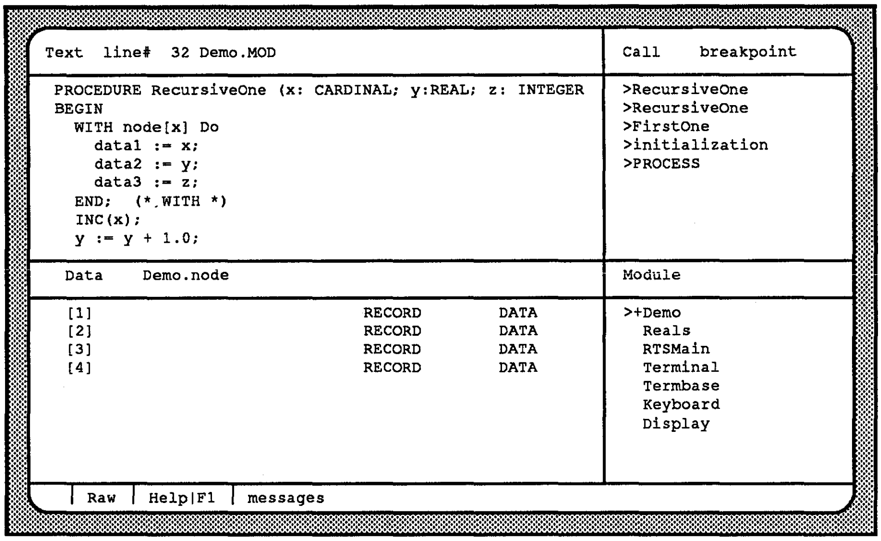
Type transfer:	Lets you change the type of a displayed variable. You can use a predefined or user-defined type. If no type is given, the variable is displayed with its original type. The Type transfer is allowed only if the type of the variable and the new type are of the same size. If you use a type of your own, the debugger prompts you for the module defining it. A type-changed variable is marked by a "**T**".
Variable:	Returns to the first level of the selected procedure or module. The first level shows the variables of the procedure or module. The Variables command can be used after you have repeatedly entered the Son command and wish to return to the first level directly, without repeatedly entering the Father command.
Examine PROCESS:	This command can be used when you select a variable of type "**PROCESS**". Otherwise, the ***PMD*** prompts you to introduce the address of the process descriptor - the content of a variable of type **PROCESS**. The Examine command displays the call chain of the process to be examined. Enter the call window command Examine break process to show the Call window of the process that was running when the program stopped. Checks to see if the process is initialized (a word with a special pattern is in all process descriptor).
Address:	Displays the address of the selected data item and updates the Raw window.

The following sample screens show the path you follow to modify the content of an array element with a record structure. First, invoke the Son command to view the elements of the variable "node" of the module "**Demo**" (Figures 7-7 and 7-8. Again, invoke the Son command to display the fields of the record "node[1]", and the value and type of each field (Figures 7-9).



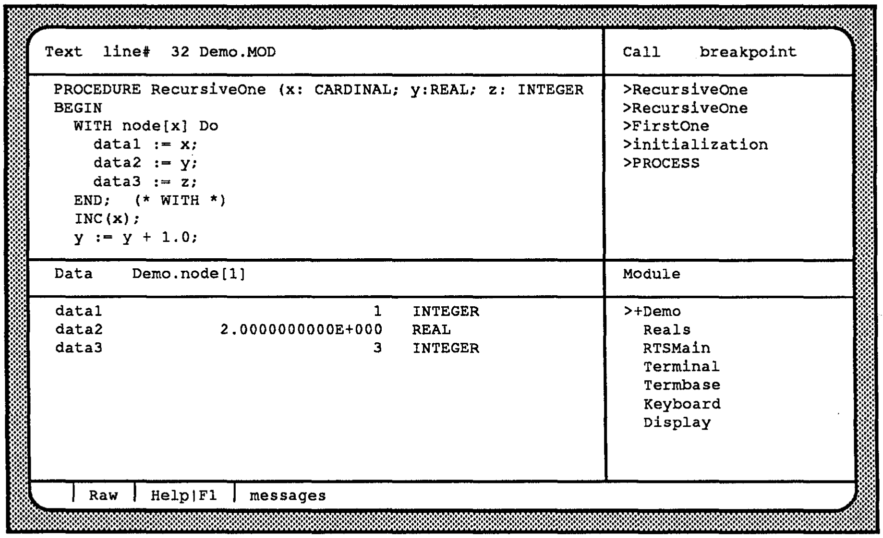
```
Text  line#  32 Demo.MOD                                  Call    breakpoint

PROCEDURE RecursiveOne (x: CARDINAL; y:REAL; z: INTEGER   >RecursiveOne
BEGIN                                                     >RecursiveOne
  WITH node[x] Do                                         >FirstOne
    data1 := x;                                           >initialization
    data2 := y;                                           >PROCESS
    data3 := z;
  END;  (* WITH *)
  INC(x);
  y := y + 1.0;

Data    Demo                                              Module

x                          1  INTEGER                     >+Demo
y           2.0000000000E+000  REAL                         Reals
z                          3  INTEGER                       RTSMain
node                          ARRAY[1..4] OF RECORD         Terminal
                                                            Termbase
                                                            Keyboard
                                                            Display

    | Raw | Help|F1 | messages
```

Figure 7-7 Sample Screen



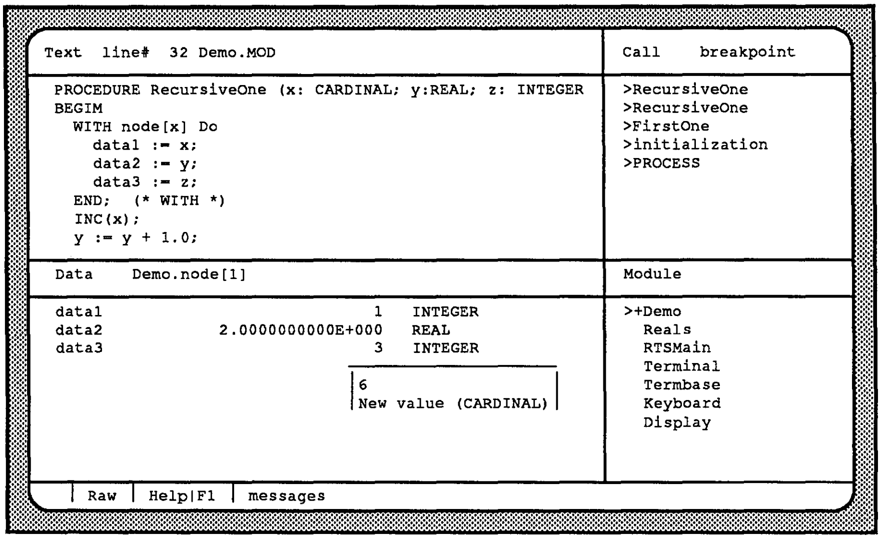
```
Text   line#  32 Demo.MOD                                  Call    breakpoint

 PROCEDURE RecursiveOne (x: CARDINAL; y:REAL; z: INTEGER   >RecursiveOne
 BEGIN                                                     >RecursiveOne
   WITH node[x] Do                                         >FirstOne
     data1 := x;                                           >initialization
     data2 := y;                                           >PROCESS
     data3 := z;
   END;   (* WITH *)
   INC(x);
   y := y + 1.0;

  Data     Demo.node                                       Module

  [1]                            RECORD        DATA        >+Demo
  [2]                            RECORD        DATA          Reals
  [3]                            RECORD        DATA          RTSMain
  [4]                            RECORD        DATA          Terminal
                                                             Termbase
                                                             Keyboard
                                                             Display

    | Raw | Help|F1 | messages
```

Figure 7-8 Sample Screen



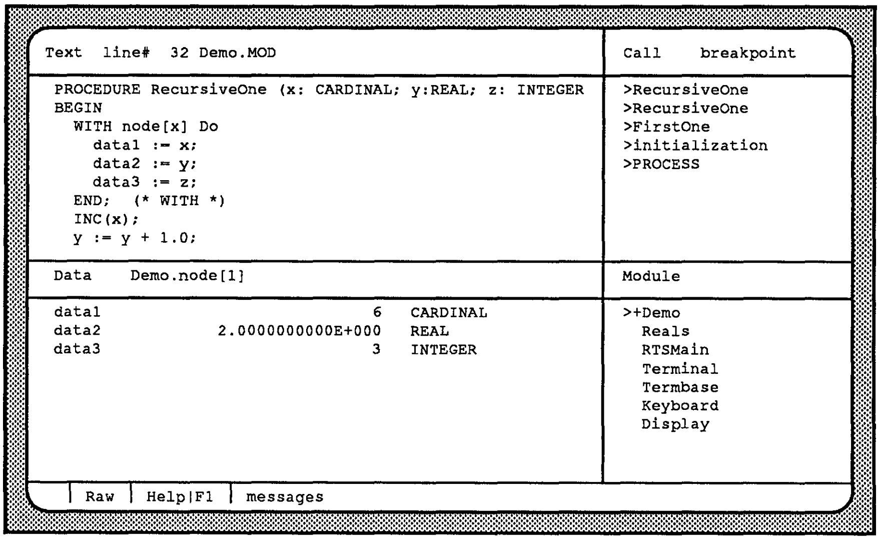
```
Text   line#  32 Demo.MOD                                  Call    breakpoint

 PROCEDURE RecursiveOne (x: CARDINAL; y:REAL; z: INTEGER   >RecursiveOne
 BEGIN                                                     >RecursiveOne
   WITH node[x] Do                                         >FirstOne
     data1 := x;                                           >initialization
     data2 := y;                                           >PROCESS
     data3 := z;
   END;   (* WITH *)
   INC(x);
   y := y + 1.0;

 Data     Demo.node[1]                                     Module

 data1                        1    INTEGER                 >+Demo
 data2             2.0000000000E+000    REAL                 Reals
 data3                        3    INTEGER                   RTSMain
                                                             Terminal
                                                             Termbase
                                                             Keyboard
                                                             Display

    | Raw | Help|F1 | messages
```

Figure 7-9 Sample Screen



```
Text   line#  32 Demo.MOD                               Call    breakpoint

PROCEDURE RecursiveOne (x: CARDINAL; y:REAL; z: INTEGER  >RecursiveOne
BEGIM                                                    >RecursiveOne
  WITH node[x] Do                                        >FirstOne
    data1 := x;                                          >initialization
    data2 := y;                                          >PROCESS
    data3 := z;
  END;  (* WITH *)
  INC(x);
  y := y + 1.0;

Data     Demo.node[1]                                    Module

data1                             1    INTEGER           >+Demo
data2              2.0000000000E+000    REAL                Reals
data3                             3    INTEGER              RTSMain
                                 ______________________     Terminal
                                |6                    |     Termbase
                                |New value (CARDINAL) |     Keyboard
                                                            Display

    | Raw | Help|F1 | messages
```

Figure 7-10 Sample Screen



```
Text   line#  32 Demo.MOD                               Call    breakpoint

PROCEDURE RecursiveOne (x: CARDINAL; y:REAL; z: INTEGER  >RecursiveOne
BEGIN                                                    >RecursiveOne
  WITH node[x] Do                                        >FirstOne
    data1 := x;                                          >initialization
    data2 := y;                                          >PROCESS
    data3 := z;
  END;  (* WITH *)
  INC(x);
  y := y + 1.0;

Data     Demo.node[1]                                    Module

data1                             6    CARDINAL          >+Demo
data2              2.0000000000E+000    REAL                Reals
data3                             3    INTEGER              RTSMain
                                                            Terminal
                                                            Termbase
                                                            Keyboard
                                                            Display

    | Raw | Help|F1 | messages
```

Figure 7-11 Sample Screen

7.7.4 Text Window

The Text window displays the text of a module or procedure. The (>) greater-than sign indicates the line in which the program, the next procedure, or where the last process transfer or interrupt occurred.

Local Commands in the Text Window

Find:	Prompts for a **PROCEDURE** or local module name (case sensitive), or a line number and, if found, the ***PMD*** sets the selected position to this **PROCEDURE**, module, or line number. This command allows you to enter either a line number or a procedure name. Wild characters are accepted (" * "," ? ").
eXchange:	Lets you switch from MOD to DEF or DEF to MOD.
Address:	Show the code address of the selected source line and updates the Raw window.

7.7.5 Raw Window

The Raw window displays the memory contents around a given address. The initial address of the selected memory location depends on the window from which you invoke the Raw window. The values are set the same way as in the *PMD*.

Local Commands in the Raw Window

Address:	Lets you enter the address of data to be displayed.
Son:	Takes the contents of the selected memory location as the new selected address. You typically enter this command to follow a linked list. (dereferencing)
Examine PROCESS:	Assumes the memory contents at the selected address is of type "**PROCESS**" that is a pointer to a process descriptor. The Examine command displays the Call window of the process. The call window command Examine break process can be used to show the Call window of the process that was running when the program crashed. It also checks the check word of the process descriptor to check if a valid process is selected.
Hexadecimal:	Decimal to hexadecimal conversion.
Decimal:	Hexadecimal to decimal conversion.
Various display modes:	**address, byte, cardinal, char, integer, longint, real, text, word**
#Address:	**ADDRESS** (hexadecimal) format.
#Byte:	**BYTE** (hexadecimal) format.
#Unsigned:	Unsigned **CARDINAL** format
#Char:	**CHAR** (octal) format. Non-printable characters are displayed as octal numbers.
#Integer:	**INTEGER.**
#Text:	**TEXT.** Non-printable characters are displayed as *IBM PC* extended characters.
#Real:	**REAL.**
#Word:	**WORD** (hexadecimal) format. (default)

7.7.6 Message Window

Version: Lets you display the version of the debugger.

7.7.7 Markers

> (greater-than) is used in the *PMD* as an execution marker to indicate active code when the program crashed. It appears in the Call, Module and Text windows.

7.7.8 Selecting an Item for Display

The *PMD* displays the position of the selected item highlighting the proper line. You may select a different item using the cursor keys or the mouse.

7.7.9 Relation between Windows

The *PMD* displays different windows at the same time. This impacts what is shown and how selections are made. The Call and Module windows are mostly used for selecting text and/or data. You can select an element and use the double click (or the menu) to update the other windows.

7.7.9.1 Update made from the Call window

When a windows update is requested from the Call window, the *PMD* shows the data and/or the text of the selected procedure. The Raw window shows the contents of the stack.

7.7.9.2 Update made from the Module window

When a windows update is requested from the Module window, the *PMD* displays the data and/or the text of the current module. The Raw window shows the global data area.

7.7.9.3 Update from the Data and Text windows

You can modify the contents of the Raw window by using the command Address of the Data or the Text window.

7.8 Consistency Checks

The *PMD* does three consistency checks:

- Between the code in memory (.PMD file or .EXE file) and the .MAP file. This check is made by using keys stored in the code and referenced by a $OK label in the map.
- Between the code in memory and the .REF file. This test is made by using the keys stored in the code and a key stored in the .REF.
- Between the .REF file and the .MOD file. This check is made by using the date of the .MOD (i.e. the date of the source file when it was compiled) stored in the .REF file. If this date is not the same as the date of the .MOD file read by the debugger, an inconsistency is signaled.

The inconsistency between the .MAP and the code in memory is very dangerous. It is extremely probable that all the information known from the .MAP is wrong. For this reason, the debugger does not display any symbolic information. It is strongly advised to relink your application.

An inconsistency between the .REF and the code in memory will make trouble only for the corresponding module. Depending on the changes made, only the data can be wrong or only the position displayed in the Text window or both can be wrong. It is advised to recompile this module and to relink the application (with a .MAP !)

An inconsistency between the .MOD and the .REF will make trouble when displaying the statement executed in the Text window. It is also advised to recompile this module and to relink the application.

NOTE

An additional check is made when a process descriptor or when an overlay descriptor is accessed (an overlay descriptor is also allocated for the main program). A field is initialized in the both descriptors with a specific value. If this value is not found, an error is signaled. This error means that you tried to analyze an incorrect part of the memory or that the memory was destroyed.

A test is also made when a .EXE is loaded to check if it is a ***Modula-2*** program. The debugger can debug programs only if the main is in ***Modula-2***.

7.9 Messages

`Already as an icon`

`Already at top level`

`ASSERT: message`

An internal error is detected into the debugger. The execution stops.

`Beginning of this ARRAY`

`Call list incomplete (BP chain invalid)`

A problem was encountered while reading the stack (memory destroyed ?)

`Call list too long (>32)`

This is a warning message which tells you that not all procedures on the stack are visible in the call list.

`Can't be iconized`

`Can't expand in an icon`

`Cmd not allowed (use zoom)`

`Cmd not allowed on a window`

`Cmd not allowed on an icon`

`Cmd not valid in DEF MODULE`

`Color changed`

`Config changes NOT saved`

You did not save the last screen configuration.

`DEF file not found`

`End of this ARRAY`

`Help file not found`

`Incorrect MAP file`
An inconsistency is detected between the .MAP file and the code. This message appears and remains in the windows to warn you.

`Incorrect REF file`
An inconsistency was detected with the .REF file. A pop up window displays the reason the first time the inconsistency is detected. This message remains in the window to remind you.

`Invalid call list`
This message is displayed in a pop-up window when a problem is encountered while reading the call list (memory destroyed ?)

`Invalid descriptor`
The overlay descriptor has no valid check word (memory destroyed ?)

`Invalid PROCESS descriptor`
The process used as a parameter of the last command has no valid check word (memory destroyed ?)

`Invalid process`
The dump cannot be analyzed, the process descriptor of the process which crashed is invalid (memory destroyed ?)

`MOD file not found`

`MODULE not found in list`

`No call list`

`No data (unknown PROCEDURE)`

`No data in this element`

`No data in this local MODULE`

`No data in this PROCEDURE`

`No global data in this MODULE`

`No global or local data`

`No selected PROCEDURE`

`No text associated`

`No text for a PROCESS`

`Not enough memory`
: Memory problem. Use Small or Big swap option.

`PROC/MODULE isn't in this text`

`REF file can't be re-opened`

`REF file not found`

`Swapping of icons not allowed`

`This border can't be moved`

`This data can't be modified`
: [Data window, Modify command]
This data cannot be modified. Usually this is for hidden types. In this case you should use the Son command to see the effective type and then you can modify the variable.

`This data isn't an ARRAY`

`This data isn't structured`

`This data is of its original TYPE`

`To modify data use Son cmd`

`Too many MODULEs (> 256)`
: The debugger cannot debug programs with more than 256 modules.

`Too small for expanding`

`TYPE not found in given MODULE`

`TYPE sizes differ`

`Wrong version of REF file: Bad structure`
: The REF file does not have the correct version (recompile the module and relink the application) or is too big.

`Wrong version of REF file: Different from OBJ`
: An inconsistency was detected between the .REF and the code in memory.

`Wrong version of text file`
: An inconsistency was detected between the .MOD and the .REF file.

```
Out of dump
Out of dump : = NIL
Out of dump : > 1 MB
```

Chapter 8
Implementation Features

WARNING

Use the features in this chapter with care, since they can conflict with the basic software of the operating system, and with the ***LOGITECH Modula-2*** system.

8.1 System Dependent Facilities

This section gives an overview of the ***LOGITECH Modula-2*** specific low-level features. **Section 8.2, Priorities and Interrupts** gives additional information on hardware dependencies.

The differences in programming for various implementations can be attributed to:

- Changes to the language itself.
- Differences in the set of available procedures and data types which reflect the structure of the machine used.
- Differences in the internal representation of data.
- Differences in the set of available modules, in particular those for handling files and peripheral devices.

The last item reflects the environmental aspects of ***Modula-2*** — such as the set of standard library modules that give access to the file system, the keyboard and the screen.

A listing of the .DEF files for the ***LOGITECH Modula-2*** library is in Section 9.2.

8.1.1 Language Extensions

Constants of type **ADDRESS** may be declared as **<segment:offset>**, where the segment and offset are **CARDINAL** numbers. The segment and offset must be constant numbers.

Example:

```
CONST int3Addr = OH:12H;

TYPE ScreenType =
        ARRAY [0..24] OF                (* rows *)
        ARRAY [0..79] OF                (* columns *)
        RECORD char, attr: CHAR END;    (* content *)

VAR screen [0B000H:0H] : ScreenType;

a := 1234:5678; (* assume 'a'of type ADDRESS *)
```

LOGITECH Modula-2 also provides for the declaration of absolute variables. Absolute variables are variables for which the programmer, rather than the ***LOGITECH Modula-2*** compiler, defines the memory address at which the variable will be located. This feature is intended to be used for memory-mapped input and output.

When declaring an absolute variable, the identifier denoting it must be followed by an address constant in brackets. The address constant defines the absolute address of the variable in memory. The variable **`screen`** in the above example is declared as an absolute variable.

8.1.2 Address Arithmetic

In ***Modula-2***, the standard module **SYSTEM** provides the type **ADDRESS**. The use of the type **ADDRESS** and the operations on objects of type **ADDRESS**, must be considered non-portable. The implementation of **ADDRESS** operations is very dependent on the architecture of the target system. The structure of a computer may restrict the operations that are possible on objects of type **ADDRESS**.

8.1.2.1 Interpretation of Objects of Type ADDRESS

Objects of type **ADDRESS** denote a particular location in memory. Type **ADDRESS** is compatible with any pointer type. Objects of type **ADDRESS** can be used as if there were two different type definitions for type **ADDRESS**:

```
TYPE ADDRESS = POINTER TO WORD;

TYPE ADDRESS = RECORD
                 OFFSET  : CARDINAL;
                 SEGMENT : CARDINAL;
               END;
```

Example:

If we assume the declarations:

```
VAR
    a        : ADDRESS;
    w        : WORD;
    off,seg: CARDINAL;
```

then the following statements are legal:

```
    a^ := w; w := a^;
    a.OFFSET  := off; off := a.OFFSET;
    a.SEGMENT := seg; seg := a.SEGMENT
    WITH a DO SEGMENT := seg END;
```

8.1.2.2 Operations Involving Objects of Type ADDRESS

A restricted set of arithmetic operations on objects of type **ADDRESS** is possible. The switch and compiler option **T** determines whether or not test code is generated for **ADDRESS** operations.

Addition and Subtraction

Addition and subtraction are allowed in expressions of type **ADDRESS**. An **ADDRESS** expression contains exactly one operand of type **ADDRESS**. All other operands must be of type **CARDINAL**. The operation is only performed with the **OFFSET** value of the **ADDRESS** - the **SEGMENT** value is never modified. If test code is on, the run-time error **`address overflow`** will occur upon an overflow of the **OFFSET** value on an addition or subtraction operation.

The standard procedures **INC** and **DEC** can also be used with variables of type **ADDRESS**. The following declarations are assumed:

```
PROCEDURE INC (VAR a:ADDRESS; k:CARDINAL);

PROCEDURE DEC (VAR a:ADDRESS; k:CARDINAL);
```

NOTE

The second parameter must be assignment compatible with type **CARDINAL**. If test code is on, negative values will generate a run-time error. Using **INC** and **DEC** is the preferred way to do **ADDRESS** arithmetic.

The following list shows the kinds of expressions involving operands of type **ADDRESS** which are valid. Each operand itself may be an expression of the corresponding type.

Operation	1st Operand	2nd Operand	Result Type
Addition	ADDRESS	CARDINAL	ADDRESS
Addition	CARDINAL	ADDRESS	ADDRESS
Subtraction	ADDRESS	CARDINAL	ADDRESS

Multiplication and Division

Multiplication and division operations are not allowed with operands of type ADDRESS. This includes:

*	/	MOD	DIV

Comparison

The comparison of two operands or expressions of type ADDRESS is allowed. Here are the restrictions and how the comparison is implemented:

equal
not-equal

A check on (non-) identity is generated:

a1 = a2 <--> (a1.SEGMENT = a2.SEGMENT) AND (a1.OFFSET = a2.OFFSET)

greater-than
greater-equal
less-than
less-equal

These are allowed only between addresses within the same segment — if the SEGMENT values of both operands are identical. They compare the OFFSET values only.

The result of these operations is undefined if the two ADDRESS operands compared have different SEGMENT values.

If test code is **ON**, the run-time error `address overflow` will occur when the SEGMENT values are not equal.

8.1.2.3 Dereferencing Pointers

The switch and compiler option "T" determines whether or not test code is generated for accessing data through pointers.

If test code is on, any pointer with an offset equal to **0FFFFH** is considered to be NIL. Therefore, any access through such a pointer is illegal and will result in a run-time error.

The predefined constant NIL, which is compatible with all pointer types, has the internal representation **0H:0FFFFH**. It is strongly recommended that no program makes use of this information. The representation of NIL is implementation dependent and subject to change without notice.

8.1.3 The Module SYSTEM

The module SYSTEM offers additional facilities to programs written in the Modula-2 language. Most of them are dependent upon the implementation or are specific to the target processor. Module SYSTEM also contains types and procedures which allow very basic coroutine handling.

Module SYSTEM is directly known to the compiler because its exported objects obey special rules that must be checked by the compiler. If a compilation unit imports objects from module SYSTEM, no symbol file need be supplied for this module. However, the declaration of these objects in the import list is required.

Furthermore, no link file exists for this module. The implementation of the pseudo module SYSTEM is realized by inline code or by calls to the ***LOGITECH Modula-2*** run-time support, generated by the compiler.

The interface of the pseudo module SYSTEM cannot be described completely with a regular ***Modula-2*** definition module. Module SYSTEM offers some features which expand the language itself. However, for easy reference, a description of module SYSTEM in a form similar to a definition module has been included in the library section of this manual.

For additional information please refer to ***Section 12*** of *Report on the Programming Language* in ***Programming in Modula-2.***

8.1.3.1 Constants Exported from Module SYSTEM

AX, BX, CX, DX, SI, DI, ES, DS, CS, SS, SP, BP

These constants denote the processor's registers. They are defined for use with the procedures **GETREG** and **SETREG** which are also provided by module **SYSTEM.**

8.1.3.2 Types Exported from Module SYSTEM

BYTE

An individually accessible storage unit (one byte). No operations except assignments and type conversions are allowed for variables of type BYTE. An actual parameter of any type that uses one byte of storage may be passed to a formal **BYTE** parameter. For convenience, small **CARDINAL** constants (**< = 255**) are also allowed as parameters.

WORD

One word of memory (two bytes). No operations except assignments and type conversions are allowed for variables of type **WORD**. An actual parameter of any type that uses one word of storage may be passed to a formal **WORD** parameter.

PROCESS

A type used for process handling.

ADDRESS

The address of any location in storage. The type **ADDRESS** is compatible with all pointer types and is itself defined as **POINTER TO WORD**. **Section 8.1.2, Address Arithmetic**, explains more on the properties and the use of type **ADDRESS.**

8.1.3.3 Functions Exported from Module SYSTEM

ADR(variable): ADDRESS

Storage address of the parameter variable.

SIZE(variable): CARDINAL

Returns the number of bytes used in storage by the parameter variable. If the variable is of type **RECORD** with variants, then a variant of maximal size is assumed.

TSIZE(type): CARDINAL
TSIZE(type, tag1const, tag2const, . . .) : CARDINAL

Yields the number of bytes used in storage by a variable of the substituted type. If the type is a record with variants, then tag constants of the last **FieldList** (see syntax in ***Programming in Modula-2***) may be substituted in their nesting order. If some or all tag constants are omitted, then the remaining variant with maximal size is assumed.

8.1.3.4 Procedures Exported from Module SYSTEM

```
NEWPROCESS      (processBody  : PROC;
             workspaceAddress : ADDRESS;
                workspaceSize : CARDINAL;
                  VAR process : PROCESS)
```

Create a new process.

processBody is the procedure to execute.
workspaceAddress is the address of the data area for the process (the workspace).
workspaceSize is the size of the workspace in bytes.

The variable process receives the created **PROCESS** object. Allow 400 bytes for system overhead in each workspace.

NOTE

If the workspace of the new process is too small and does not allow a reasonable initialization, the process that calls NEWPROCESS is terminated with a stack overflow.

TRANSFER (VAR fromProcess, toProcess : PROCESS)

Save the current process state in **fromProcess**, and resume the execution of the process in **toProcess.**

```
IOTRANSFER (VAR interruptHandler: PROCESS;
            interruptedProcess: PROCESS;
            interruptVectorNumber: CARDINAL)
```

Save the current process state in **interruptHandler**, and resume the execution of the process in **interruptedProcess.** The occurrence of the designated interrupt has the effect of **TRANSFER (interruptedProcess, interruptHandler).**

LISTEN

Temporarily lower the priority of the calling process and allow pending interrupts to come through.

GETREG (register: CARDINAL; VAR value: BYTEorWORD)

SETREG (register: CARDINAL; value: BYTEorWORD);

These two procedures are used to set and to retrieve the contents of machine registers. They generate in-line code, and are particularly useful in conjunction with the special procedures CODE and SWI (software interrupt) described below. The registers AX, BX, CX, DX, SP, BP, SI, DI, ES, CS, SS, and DS are accessible where SP, BP, SS and CS cannot be used with SETREG. For register only the register constants provided by module SYSTEM should be used.

If the actual argument for value is a variable in one byte, only the lower half of the register is affected. For example, in SETREG (AX, ch), where ch is declared to be a CHAR, only the AL register is modified.

WARNING

Utmost care must be exercised when using GETREG and SETREG. It must be kept in mind that expression evaluation and address computation use registers and therefore might destroy the value of a register already set by SETREG or to be read by GETREG. It is impossible for the compiler to recognize such a situation and the programmer must take full responsibility.

Only constants, or variables and value parameters which are declared local to the procedure calling GETREG or SETREG, should be used for the second argument. This argument should be of a simple type. It should neither be an expression, contain a function call, index an array, nor be a global (module) variable or a VAR parameter. If necessary, input parameter values should be copied to local variables of simple types which can be used when calling SETREG. Only local variables of simple types should be used with GETREG. If necessary, their values should be copied to the real output parameters. If there are sequences of calls to SETREG or GETREG, no other statements should break such a sequence. All local copies of input values should be made before the first call to SETREG, and the values of the local variables should be copied back after the last call to GETREG.

Unpredictable effects may result from failure to heed this warning.

CODE (code1Const, code2Const, ... : BYTE)

Insert binary machine instructions into the code. A call to **CODE** inserts the constant values, **code1Const, code2Const**, etc., in-line as executable code.

SWI(interruptVectorNumber: CARDINAL)

This procedure is used to generate a software interrupt. It compiles into an **INT** instruction. The parameter must be a constant.

If you are using the procedure **SWI** to call the *IBM-PC* **ROM BIOS** or to call any other assembly routines, we strongly recommend that you save and restore the base pointer register **BP**. The value of the **BP** register is essential to *LOGITECH Modula-2* because it is used to access local variables and procedure parameters.

To save and restore the **BP** register, use procedure **CODE**, which is also provided by module **SYSTEM**. Insert `CODE(55H);` right before, and `CODE(5DH);` right after the call to **SWI**. This pushes and pops the **BP** register to/from the stack, so that its value will be preserved.

ENABLE
DISABLE

Calls to the procedures **ENABLE** and **DISABLE** compile into **STI** and **CLI** instructions, which enables or disables interrupts.

Note: Any call to the operating system, or any input or output by means of the *LOGITECH Modula-2* library may have the effect of enabling interrupts, thus undoing a previous call to **DISABLE**.

INBYTE (port: CARDINAL; VAR value: BYTEorWORD)
OUTBYTE (port: CARDINAL; value: BYTEorWORD)

Get or put a byte value from or to the specified I/O port.

INWORD (port: CARDINAL; VAR value: WORD)
OUTWORD (port: CARDINAL; value: WORD)

Get or put a word value from or to the specified I/O port.

DOSCALL (functionNumber: CARDINAL; ...)

It generates a ***DOS*** function call via software interrupt 21H. The parameter list is variable, depending on the first parameter, which must be a constant and indicates the number of the ***DOS*** function. The appendix contains a detailed description of the available DOSCALLs.

Because the parameters of **DOSCALL** must be given to ***DOS*** in registers, no complicated expressions should be used. The compiler might easily run out of registers, resulting in compiler error 204.

EXTCALL (Procname : ARRAY of CHAR);

Procname must be a constant string. It tells the compiler to call a non ***Modula-2*** procedure. It is up to you to take care of the parameter passing and calling conventions, perhaps in **CODE** statements. (See **Chapter 6, Interfacing Other Languages**).

8.1.4 Data Representation

The data types have the following internal representation in *LOGITECH Modula-2* :

BYTE	One byte.
BOOLEAN	One byte, **TRUE=1, FALSE=0.**
CHAR	One byte, ASCII character set.
Enumeration Types	One byte, elements are numbered **0..255.**
WORD	Two bytes.
INTEGER	Two bytes, **-32768..32767**, two's complement notation, least significant byte first.
LONGINT	Four bytes, **-2147483648 . . 2147483648**, twos complement notation, least significant byte first.
CARDINAL	Two bytes, **0..65535**, least significant byte first.
Subrange Types	Same representation as the base type.
REAL	Eight bytes, ***Intel 8087*** double precision format (IEEE Floating Point standard).
SET	The size of a SET is the number of bytes obtained by dividing the number of elements in the SET (up to **256**) by **8** and rounded to the next higher integer. The elements are associated to the bits consistently with the above pictures.
BITSET	Two bytes. If we number the elements of a set from **0** to **15**, the representation in a memory word is:

7 6 5 4 3 2 1 0	15 14 13 12 11 10 9 8
low byte	high byte

POINTER **PROC** **PROCEDURE** **ADDRESS** **PROCESS**	Four bytes. The first two bytes (lower address) hold the offset value (lower byte first) and the second two bytes hold the segment value (lower byte first).
ARRAY	An array is stored as a contiguous sequence of elements, with the indices in ascending order, the right-most index varying most quickly. If the base type fits in one byte (**CHAR**, **BOOLEAN**, **enumeration**) the elements are stored in sequential bytes. Otherwise, each element is stored on a word boundary (at an even address).
RECORD	The fields of a record are allocated in the order in which they are declared. The first field has the lowest address. If you select the **Alignment** option, fields with a size other than one byte are allocated on even addresses. Therefore, dummy bytes are included after odd sized elements.
Opaque Types	**Opaque Types** are always allocated four bytes, regardless of their actual implementation.

8.1.5 Type Conversion and Type Transfer

There are two ways to deal with the "strong typing" of *Modula-2*: type conversion and type transfer.

Type Conversion

Type conversion provides the means to convert data from one type into another one, regardless of the internal representation. This is the system independent and portable way to convert data from one type to another. Therefore, whenever possible, type conversion should be used rather than type transfer. The procedures to make the conversion are built-in, standard procedures, or part of the *LOGITECH Modula-2* library. They are as follows:

Standard Functions

CHR
ORD
VAL
FLOAT
TRUNC

Library Functions

MathLib0.real
MathLib0.entier

Type conversion works by calculating a new value of a new type which corresponds to the value to be converted.. Code may be executed to perform the conversion, and range checks are done for the resulting values.

Type Transfer

The second way is referred to as type transfer, or sometimes, as type coercion. This method is system dependent — it depends on the internal representation of data. Therefore, use type transfers with utmost care, and avoid them whenever possible.

With a type transfer, no conversion of data takes place. The data is simply interpreted in a different way, according to the new type structure.

Modula-2 lets you use an identifier of a type, either a standard type like **CHAR**, or any user-defined type, as if it were a function procedure. The compiler does not produce any code for type transfers. A type transfer simply indicates that a value shall be interpreted in a different way.

A type transfer is only allowed if the object is of the same size as objects of the new type. When transferring a variable of type **T1** into type **T2**, the following relation must be true:

```
SYSTEM.TSIZE (T1) = SYSTEM.TSIZE (T2)
```

When using type transfer instead of type conversion, be aware of the internal representation of data. Your programs may not run on other machines or with other implementations of *Modula-2*.

Example 1: Interpret the value of a SET as a CARDINAL

```
VAR   b : BITSET;   (* 'b' and 'c' are both    *)
      c : CARDINAL; (* represented as 2 bytes  *)

      b : = {0,5,15};
      c : = CARDINAL(b); (* c = 2**0 + 2**5 + 2**15 *)
```

Example 2: Use a CARDINAL value in an INTEGER expression

```
VAR   i : INTEGER;
    c : CARDINAL;

    i : = 2*i + INTEGER (c);
```

This second example illustrates an abuse of the type transfer. What was really meant was a conversion to integer. The correct solution is:

```
    i : = 2*i + VAL (INTEGER, c);
```

8.2 Priorities and Interrupts

8.2.1 Use of Priorities

Priorities can be specified in the header of a module. They are allowed in program and implementation modules, as well as in local modules declared inside of another module. Priorities are used to control the occurrence of interrupts. When no priority is specified, all interrupts may occur.

However, when a program is running at a certain priority, only interrupts of a higher priority will be accepted. At the highest priority all interrupts are disabled. Note also that running at the lowest, specified priority is very different from running without any priority.

A priority module is entered upon the execution of its module initialization code or upon a call of an exported procedure. A priority module is left upon return from its initialization code or upon return from an exported procedure. When entering a priority module, the interrupt control system (hardware and software) is set such that interrupts of a priority lower or equal to the one specified in that module are not passed to the processor. When leaving a priority module, the interrupt control system is reset to the state it was prior to entering that module. The procedure **LISTEN**, from module **SYSTEM**, allows a process to lower its priority temporarily. During the execution of the procedure **LISTEN** the interrupt control system is set such that all pending interrupts are accepted.

Inside a priority module, calls to procedures of other priority modules with a lower priority than that of the module with the call statement are not allowed. When this situation is detected by the compiler, an appropriate error message is produced (error 161). If a procedure of a module with no specified priority is called, the current priority remains unchanged. If a procedure of a module with higher priority is called, that higher priority becomes effective during execution of the called procedure. The old priority is restored upon return from that procedure.

Priorities are attached to processes. Upon a **TRANSFER** or **IOTRANSFER** to a process running at another priority, the interrupt control system is switched to the priority of the process which will be activated. The same holds true for the implicit coroutine transfer which occurs upon an interrupt.

When a subprogram terminates, the priority is set back to the value which was effective when the subprogram was loaded.

8.2.2 Priority Levels

Both the *LOGITECH Modula-2* compiler and the *LOGITECH Modula-2* run-time support only allow for a fixed range of priority levels. Eight priority levels are supported with values ranging from 0 (lowest level) to 7 (highest level). If a module priority is specified with a value out of this range, the compiler produces an appropriate error message (error 80).

NOTE

Do not confuse **software priority level** with **hardware priority mask.** The mapping between the two is explained in Section 8.2.4.2.

8.2.3 Interrupt Handling

There are three main ways to handle interrupts in *LOGITECH Modula-2* :

8.2.3.1 Standard Method with IOTRANSFER

In "standard" *Modula-2*, the procedure **IOTRANSFER** from module **SYSTEM** allows for the implementation of interrupt handlers. After the call to **IOTRANSFER** the interrupt handler is installed and is waiting for the specified interrupt. However, on *8086* based systems, the system needs to be notified that interrupts from the corresponding device may now occur. In *LOGITECH Modula-2* , the module **Devices** provides the capability to enable and disable interrupts from a device. After an interrupt handler has been installed, module '**Devices**' should be used to enable interrupts from the corresponding device.

An interrupt handler should not call the operating system, for instance to write to the terminal or to a file. If the operating system is not reentrant, such a call may crash the whole system. In general, operating systems that do not support multi-tasking, for instance *DOS 2.0*, are not reentrant.

Please refer also to the definition module **Devices** and to the sample device driver **InputDevice** at the end of this section. Module **InputDevice** illustrates how an interrupt handler should be programmed with *LOGITECH Modula-2* .

8.2.3.2 Faster Method with IOTRANSFER

The standard method using **IOTRANSFER** as described in the previous section, associates a process with the next occurrence of the specified interrupt only. The procedure **InstallHandler** provided by module **Devices** allows you to install an interrupt handler that will be removed upon the proper termination. It associates a process, the interrupt handler, permanently with a particular interrupt. While it is not required to install an interrupt handler in this way, it may be useful for handling time critical interrupts. Installing an interrupt handler permanently improves the performance, by about 20 percent, of **IOTRANSFER** and of the implicit coroutine transfer that takes place when the interrupt occurs. **InstallHandler** must only be called after the process has been created (by means of NEWPROCESS) and before the process has called IOTRANSFER. For instance, it may be called at the beginning of the code of the process.

8.2.3.3 Low Level Interrupt Handling

This is the fastest method to handle interrupts, but also the least portable. Unlike the previous two methods, this implementation doesn't perform a context switch on interrupts, but uses the current stack to handle the interrupt. This provides a great improvement in speed because the overhead of two transfers is removed.

One disadvantage of this method is that the debug utilities do not support the debugging of interrupt service routines, because the state of the stack does not have the usual form.

The **RTSIntPROC** module lets you install such Interrupt Service Routines. The procedure installed as **ISR** must be a **PROC**, but does not have to save registers or similar functions, because the module **RTSIntPROC** saves all registers and sends the End-Of-Interrupt command to the interrupt controller before the call to the ***Modula-2*** procedure.

The procedure is executed "Interrupts Disabled". Thus, the procedure does not need to be in a priority module (and as the stack and context is unpredictable, it is not allowed in a priority module). As the procedure is executed "Interrupts Disabled", it must be fast to allow other interrupts to be serviced.

The procedure must not call ***DOS*** directly or indirectly, because ***DOS*** is not re-entrant, and the interrupt **PROC** may interrupt any running code, including ***DOS***, depending when the interrupt occurs. For example, it shall not use library modules making Input/Output like **FileSystem**, **Terminal**, **InOut**, etc.

The following code shows a module which allows the installation of a *Modula-2* procedure as an interrupt service routine:

```
MODULE ModulaISR;

FROM RTSIntPROC   IMPORT SetIntPROC, FreeIntPROC;
FROM SimpleTerm   IMPORT WriteString, WriteLn, KeyPressed;

VAR
      BreakPressed : BOOLEAN;

   PROCEDURE  ISR;
   BEGIN
      BreakPressed := True;           (* signal the event to the outside          *)
   END ISR;

BEGIN
   BreakPressed := FALSE;
   SetIntPROC ( ISR, 27 );
   LOOP
      IF BreakPressed THEN
         BreakPressed := FALSE;       (* reset the event                          *)

         (* The write MUST be done outside the ISR, because Write uses DOS calls,  *)
         (* and DOS is not re-entrant.  This is the way to signal an event from    *)
         (* an ISR and take it into account, and make the heavy or time-consuming  *)
         (* work outside the ISR.                                                  *)

         WriteString ( "Break !" );   (* make the time-consuming work             *)
         WriteLn;
      END;
   IF KeyPressed() THEN EXIT END;
   END;
   FreeIntProc;                       (* releases all installed ISRs              *)
END ModulaISR
```

8.2.3.4 How to Cope With Non-Reentrancy of MS-DOS

The non-reentrancy of ***MS-DOS*** appears to be a problem when writing a real-time kernel in ***Modula2*** (as in other languages). The basic principle is to avoid task switching while ***DOS*** is in a 'critical section'. There is an undocumented ***DOS*** call (34H) which can be used to determine whether ***DOS*** is in such a critical section. Since DOSCALL 34H is not documented, it is not supported by the ***LOGITECH Modula-2 Compiler.*** The following program extract shows you how to get access to this information:

```
MODULE scheduler;

   FROM SYSTEM IMPORT
      ADR, ADDRESS, SETREG, GETREG, SWI, AX, ES, BX;

   TYPE
      BooleanPtr = POINTER TO BOOLEAN;

   VAR
      criticalSectionPtr : BooleanPtr;
      aux                : ADDRESS;

BEGIN
  SETREG (AX, 3400H);
  SWI (21H);
  GETREG (ES, aux.SEGMENT);
  GETREG (BX, aux.OFFSET);
  criticalSectionPtr := BooleanPtr(aux);

END scheduler.
```

In the scheduler routine which actually performs the task switching, one must test the critical section flag in ***DOS***:

```
IF criticalSectionPtr^ THEN
   (*
      don't do the transfer to the waiting process,
      but let the interrupted process continue

   *)
   TRANSFER(currentProcess,interruptedProcess);
ELSE
   (* transfers to waiting process *)
   TRANSFER(currentProcess, waitingProcess);
END;
```

A similar check can be done to avoid ***DOS*** function calls in an interrupt handler routine, while ***DOS*** is in a critical section.

8.2.4 Implementation Notes

LOGITECH Modula-2 implements priorities and device handling through the mask register of the interrupt controller in the *8086* system. The corresponding code is part of the *LOGITECH Modula-2* run-time support.

8.2.4.1 The Device Mask

The run-time support maintains a device mask that indicates from which devices interrupts are enabled. When a program is not running at any priority, the mask register of the interrupt controller is identical to this device mask. The initial value of the device mask corresponds to the value of the interrupt controller mask at the time when the *LOGITECH Modula-2* program was started.

The library module Devices provides procedures that allow a program to enable or disable interrupts from a device. These procedures are implemented by calls to functions of the run-time support, which modify the device mask. The device numbers used by module Devices and by the *LOGITECH Modula-2* run-time support correspond to the order and meaning of the bits in the mask register of the interrupt controller.

The run-time support maintains only one copy of the device mask. Thus, the device mask is shared among all processes and any subprograms of a *LOGITECH Modula-2* program.

8.2.4.2 The Priority Masks

To each priority level a particular priority mask corresponds, which masks out the interrupts from all devices with the same or a lower priority. The order and meaning of the bits in the priority mask are the same as those in the device mask and in the mask register of the interrupt controller. The mapping between the priorities and the priority masks is done by the run-time support. The value of the priority level is used as an index to a table of priority masks.

The table of priority masks is initialized as follows: It masks bit seven for priority level zero, the lowest priority. It masks bit six and seven for priority level one, and so on. For priority level seven, the highest priority, all bits in the mask are set such that all interrupts are disabled. These default settings correspond to the *IBM-PC* hardware. If necessary, the values in this table may be modified to implement a different priority scheme that reflects the hardware properties of a given *8086* based system.

8.2.4.3 The Interrupt Controller Mask

When a program is not running at any priority, ***LOGITECH Modula-2*** sets the mask register of the interrupt controller such that it is identical to the device mask. If a program is running at a particular priority, the mask register of the interrupt controller is set to the logical **OR** of the device mask and the corresponding priority mask. In this way, all interrupts are disabled which are masked out either in the device mask or in the current priority mask.

The field **PriorityMask** of the process descriptor holds the priority mask that corresponds to the priority at which the process is running. When creating a new process (procedure **NEWPROCESS**), the initial value of the priority mask in the process descriptor is zero. This initial value indicates that the process is not running at any priority. If the procedure which constitutes the process is declared in a priority module, its priority becomes effective when the process is started. A process starts execution upon the first **TRANSFER** of control to it, after it was created by **NEWPROCESS.**

The mask register of the interrupt controller is always equal to the logical **OR** of the current device mask and the priority mask that corresponds to the priority at which the current process is running. When a coroutine transfer occurs upon a call to **TRANSFER**, **IOTRANSFER**, or upon an interrupt, the mask register of the interrupt controller is set according to the priority of the process that takes control and according to the value of the device mask. The mask register of the interrupt controller is also set accordingly whenever the priority changes because of a call to, or a return from, a priority module. When the device mask is modified, the mask register of the interrupt controller is updated according to the new device mask and according to the priority mask of the current process.

8.2.4.4 Monitor Entry and Exit

Priority modules are also called **monitors**. When entering or leaving a monitor, some code is executed to change the priority of the current process. This code is part of the ***LOGITECH Modula-2*** run-time support.

The compiler generates a call to the run-time support (**RTS** call) in the procedure entry code (to the **Monitor Entry** function) and in the procedure exit code (to the **Monitor Exit** function) for every procedure exported from a priority module. The procedure **LISTEN** from module **SYSTEM** is translated to another RTS call, the **Listen** function.

The **Monitor Entry** function is called after the possible stack-test and after the stack pointer is decremented by the size of the local data. It saves the current priority mask, from the process descriptor of the current process, onto the stack of the entered procedure. The new priority is used as an index in a table that contains the value of the priority mask for each priority level. The new priority mask is stored in the process descriptor. The mask register of the interrupt controller is set to the logical OR of the new priority mask and the current device mask.

The **Monitor Exit** function restores the old priority mask from the top of the stack back into the process descriptor. It also sets the mask register of the interrupt controller to the logical OR of the old priority mask and the current device mask. Unless the device mask has been changed while running on priority, the mask register of the interrupt controller will have the same value as before entering the priority module.

The **Listen** function first sets the current priority to **no priority**, in a way similar to the **Monitor Entry** function. The value of the priority mask for **no priority** is not stored in the table of priority masks. The mask for **no priority** has all bits set to zero. Therefore, the mask register of the interrupt controller will be equal to the device mask. The **Listen** function then sets the interrupt enable flag of the processor. At this point, all pending interrupts may come through, if they were enabled in the device mask. After the execution of a no-operation instruction, the **Listen** function restores the old priority in a way similar to the **Monitor Exit** function.

8.2.5 The Definition Module for "InputDevice"

```
DEFINITION MODULE InputDevice;
(*
   Sample Input Device

   This is the sample interface definition for a small input device driver, which
   shows how interrupt driven devices should be handled in LOGITECH Modula-2.
   A corresponding scheme can be used for interrupt driven output devices.
*)

   EXPORT QUALIFIED
      ReadInfo;

   PROCEDURE ReadInfo (VAR info: Information);
   (*
      get information from the device, where 'Information' might be
      of type 'CHAR' for a character device
   *)

END InputDevice.
```

8.2.6 The Implementation Module for "InputDevice"

```
IMPLEMENTATION MODULE InputDevice [priority];
(*
   Sample Input Device

   This is a small sample input device driver, which shows how interrupt driven
   devices should be handled in LOGITECH Modula-2.

   A corresponding scheme can be used for interrupt driven output devices
*)

   FROM SYSTEM IMPORT
      PROCESS, NEWPROCESS, TRANSFER, IOTRANSFER, ADR, SIZE, BYTE, ADDRESS;

   FROM RTSMain IMPORT
      InstallTermProc;

   FROM Devices IMPORT
      GetDeviceStatus, SetDeviceStatus, SaveInterruptVector, RestoreInterruptVector;
      InstallHandler;

   CONST
      device = ??;
      (* bit number in interrupt controller mask *)

      interruptVectorNumber = ??;
      (* interrupt vector used by device *)
```

```
  VAR
      mainP, driverP: PROCESS; (* Modula-2 coroutines *)

      workspace: ARRAY [0..??] OF BYTE;
      (* workspace for driver coroutine *)

      oldInterruptVector : ADDRESS;

      oldDeviceStatus: BOOLEAN;

      activ: BOOLEAN;
      (*
         indicates whether the device driver has been activated
      *)


      PROCEDURE ReadInfo (VAR info : Information);
      BEGIN
      (* get info from a buffer *)
      END ReadInfo;

PROCEDURE DeviceDriver;
   BEGIN
   (*
      here we could associate the process permanently to
      the given interrupt vector number by:
         InstallHandler(driverP, interruptVectorNumber);
      This call improves the performance of the interrupt handling
   *)
   LOOP
      IOTRANSFER(driverP, mainP, interruptVectorNumber);
      (* handle the interrupt, put info into a buffer *)
   END; (* LOOP *)
END DeviceDriver;

PROCEDURE StartDevice;
   BEGIN
      IF NOT activ THEN
         SaveInterruptVector ( interruptVectorNumber,
                               oldInterruptVector);
         (* save interrupt vector used by device *)

         GetDeviceStatus(device, oldDeviceStatus);
         (* save old device status (interrupts enabled/disabled) *)
         activ := TRUE;
         NEWPROCESS (DeviceDriver, ADR (workspace), SIZE (workspace), driverP);
         (* create a Modula-2 process for the driver *)

      TRANSFER(mainP, driverP);
      (* transfer control to the driver process *)

      SetDeviceStatus(device, TRUE);
      (* allow (enable) interrupts from the device *)
   END;
END StartDevice;
```

```
PROCEDURE StopDevice;
   BEGIN
      IF activ
         THEN activ := FALSE;
      SetDeviceStatus(device, oldDeviceStatus);
      (* restore the original device status (interrupts enabled/disabled) *)

      RestoreInterruptVector (interruptVectorNumber, oldInterruptVector);
      (* restore the original value of the interrupt vector used by the device *)
   END;
END StopDevice;


PROCEDURE InitDevice;
   BEGIN
      (* initialize device if necessary *)
   END InitDevice;

   BEGIN
      activ := FALSE;
      InitDevice;
      StartDevice;
      InstallTermProc(StopDevice);
      (*
         install 'StopDevice' as a termination routine, in order to properly stop
         the device driver when the program that uses the driver terminates
      *)
END InputDevice.
```

8.3 DOSCALL

The **DOSCALL** procedure must be imported from the **SYSTEM** module. It provides a rather simple way to access the underlying operating system from programs written in ***Modula-2***. For the description of each of these functions we refer to the corresponding ***MS-DOS*** or ***PC-DOS Manual***. The actual parameters of the procedures should not be very complicated. The compiler might easily run out of registers.

The first line is a ***Modula-2*** procedure declaration. The second line notes for each parameter the register(s) in which it is passed. The type **BYTEWORD** (which doesn't exist in ***Modula-2***) means that any type compatible with **BYTE** or **WORD** is possible for the actual parameter.

Example:

```
DOSCALL (15;
        FCBAddr          : ADDRESS;
        VAR returnCode : BYTEWORD);
        AH DS            : DX AL
```

possible use:

```
VAR  FCB       : ARRAY[0...35] OF CHAR;
     returnVal : CARDINAL

DOSCALL(15, ADR(FCB), returnVal);
IF returnVal =...THEN
```

The standard procedure **DOSCALL** has a variable parameter list. This parameter list depends on the first parameter that must be a constant. This constant is the number of the *DOS* function to be called.

The formats of these functions are:

Function 0H: Program Terminate

```
DOSCALL (0H)
         AH
```

Function 1H: Keyboard Input

```
DOSCALL (1H; VAR char:BYTEWORD);
         AH   AL
```

Function 2H:Display Output

```
DOSCALL (2H; char:BYTEWORD);
        AH   DL
```

Function 3H: Auxiliary Input

```
DOSCALL (3H; VAR char:BYTEWORD);
         AH   AL
```

Function 4H: Auxiliary Output

```
DOSCALL (4H; char:BYTEWORD);
         AH   L
```

Function 5H: Printer Output

```
DOSCALL (5H; char:BYTEWORD);
         AH   DL
```

Function 6H: Direct Console I/O

```
DOSCALL (6H; OFFH; VAR char:BYTEWORD;
         AH   DL     AL

VAR ready : BOOLEAN); (input)
            ZF

DOSCALL (6H; char:BYTEWORD); (output)
         AH   DL
```

Function 7H: Direct console Input without echo

```
DOSCALL (7H; VAR char:BYTEWORD);
         AH   AL
```

Function 8H: Console input without echo

```
DOSCALL (8H; VAR char:BYTEWORD);
         AH   AL
```

Function 9H: Print String

```
DOSCALL (9H; stringaddr:ADDRESS);
         AH  DS : DX
```

Function 0AH: Buffered Keyboard input

```
DOSCALL (0AH; stringaddr:ADDRESS);
          AH   DS : DX
```

Function 0BH: check standard input status

```
DOSCALL (0BH; VAR status:BYTEWORD);
         AH   AL
```

Function 0CH: Clear standard input buffer and invoke a standard input function

The second parameter (input function) determines the form of the parameter list.
It must be one of the constants (functions) 1H, 6H, 7H, 8H, or 0AH.

```
DOSCALL (0CH; 1H; VAR char:BYTEWORD);
         AH   AL      AL

DOSCALL (0CH; 6H; VAR char:BYTEWORD;
         AH   AL      AL
         [DL = 0FFH implicitly]
         VAR ready:BOOLEAN);
         ZF

DOSCALL (0CH; 7H; VAR char:BYTEWORD);
         AH  AL       AL

DOSCALL (0CH; 8H; VAR char:BYTEWORD);
         AH   AL      AL

DOSCALL (0CH; 0AH; stringaddr:ADDRESS);
          AH   AL     DS : DX
```

Function 0DH: Disk reset

```
DOSCALL (0DH)
         AH
```

Function 0EH: Select Disk

```
DOSCALL(0EH; drive : BYTEWORD;
         AH   DL

VAR nrofdrives : WORD);
         AL
```

Function 0FH: Open File

```
DOSCALL (0FH; FCBaddr:ADDRESS;
         AH  DS:DX

VAR returnCode : BYTWORD);
         AL
```

Function 10H: Close File

```
DOSCALL (10H; FCBaddr:ADDRESS;
          AH   DS : DX

VAR returnCode : BYTEWORD);
          AL
```

Function 11H: Search for the first entry

```
DOSCALL (11H; FCBaddr:ADDRESS;
         AH   DS : DX

VAR returnCode : BYTEWORD);
         AL
```

Function 12H: Search for the next entry

```
DOSCALL (12H; FCBaddr : ADDRESS;
          AH  DS:DX

VAR returnCode:BYTEWORD);
          AL
```

Function 13H: Delete File

```
DOSCALL (13H; FCBaddr : ADDRESS;
         AH  DS:DX

VAR returnCode : BYTEWORD);
         AL
```

Function 14H: Sequential Read

```
DOSCALL(14H; FCBaddr : ADDRESS;
         AH   DS : DX

VAR returnCode : BYTEWORD);
         AL
```

Function 15H: Sequential Write

```
DOSCALL (15H; FCBaddr : ADDRESS;
          AH   DS : DX

VAR returnCode : BYTEWORD);
          AL
```

Function 16H: Create File

```
DOSCALL (16H; FCBaddr : ADDRESS;
         AH   DS : DX

VAR returnCode : BYTEWORD);
         AL
```

Function 17H: Rename File

```
DOSCALL (17H; FCBaddr : ADDRESS;
          AH   DS : DX

VAR returnCode : BYTEWORD);
          AL
```

Function 19H: Current Disk

```
DOSCALL (19H; VAR currDrive : BYTEWORD);
         AH   AL
```

Function 1AH: Set Disk Transfer Address

```
DOSCALL (1AH; DTA : ADDRESS);
          AH   DS : DX
```

Function 1BH: Allocation table information

```
DOSCALL (1BH; VAR FATaddr : ADDRESS;
          AH   DS : BX

VAR nrallocUnits, nrSectors,
          DX      AL

sectSize : BYTEWORD);
          CX
```

Function 1CH: (not implemented)

Function 21H: Random Read

```
DOSCALL(21H; FCBaddr:ADDRESS;
          AH      DS : DX

VAR returnCode : BYTEWORD);
          AL
```

Function 22H: Random Write

```
DOSCALL(22H; FCBaddr:ADDRESS;
          AH   DS : DX

VAR returnCode : BYTEWORD);
          AL
```

Function 23H: File Size

```
DOSCALL(23H; FCBaddr : ADDRESS;
        AH   DS : DX

VAR returnCode : BYTEWORD);
        AL
```

Function 24H: Set Random Record Field

```
DOSCALL(24H; FCBaddr : ADDRESS);
        AH   DS : DX
```

Function 25H: Set Interrupt Vector

```
DOSCALL(25H; vectorVal : ADDRESS;
             IntNumber : BYTEWORD);
        AH   DS : DX      AL
```

Function 26H: Create a new program segment

```
DOSCALL(26H; progSegment:BYTEWORD);
        AH   DX
```

Function 27H: Random Block Read

```
DOSCALL(27H; FCBaddr:ADDRESS;
        AH   DS:DX

VAR nrofBytes:BYTEWORD;
        CX

VAR returnCode:BYTEWORD);
        AL
```

Function 28H: Random Block Read

```
DOSCALL(28H; FCBaddr:ADDRESS;
        AH   DS:DX

VAR nrofBytes:BYTEWORD;
        CX

VAR returnCode:BYTEWORD);
        AL
```

Function 29H: Parse Filename

```
DOSCALL (29H; FCBaddr : ADDRESS;
                 mode : BYTEWORD;
        AH   ES:D      AL

VAR stringaddr : ADDRESS;
        DS:SI

VAR returnCode : BYTEWORD);
        AL
```

Function 2AH: Get Date

```
DOSCALL(2AH; VAR year:WORD; VAR monthday:WORD);
        AH       CX             DX
```

Function 2BH: Set Date

```
DOSCALL(2BH; year:WORD; monthday:WORD;
        AH   CX         DX

VAR returnCode:BYTEWORD);
        AL
```

Function 2CH: Get Time

```
DOSCALL(2CH; VAR hourminute, secondmillisec:WORD);
        AH       CX          DX
```

Function 2DH: Set Time

```
DOSCALL(2DH; hourminute, secondmillisec:WORD;
        AH   CX          DX

VAR returnCode:BYTEWORD);
        AL
```

Function 2EH: Set/Reset Verify Switch

```
DOSCALL(2EH; zero:BYTEWORD; onoff:BYTEWORD);
        AH   DL             AL
```

8.3.1 Extensions for DOS 2.0

Function 2FH: Get DTA

```
DOSCALL (2FH; VAR DTAaddr: ADDRESS);
         AH   ES:BX
```

Function 30H: Get DOS version

```
DOSCALL (30H; VAR major, minor: BYTE);
         AH   AL       AH
```

Function 31H: Terminate and remain resident

```
DOSCALL (31H; exitCode : BYTEWORD;
         AH   AL

paragraphs : WORD);
         DX
```

Function 33H: Ctrl-Break-Check

```
DOSCALL(33H; mode:BYTEWORD; VAR state:BYTE);
         AH   AL       DL
```

Function 35H: Get Vector

```
DOSCALL(35H; vector:BYTEWORD; VAR vector:ADDRESS
         AH   AL       ES:BX
```

Function 36H: Get disk free space

```
DOSCALL(36H; drive:BYTEWORD; VAR valid:BYTEWORD;
         AH   DL       AX

VAR availClusters:BYTEWORD;
         BX

VAR totclust:BYTEWORD;
         DX

VAR bytesPerSect:BYTEWORD);
         CX
```

Function 38H: Return Country dependent information

```
DOSCALL(38H; buffAddr:ADDRESS; fctcode:BYTEWORD);
         AH   DS:DX       AL
```

Function 39H: Create a subdirectory (MKDIR)

```
DOSCALL(39H; stringaddr:ADDRESS;
         AH   DS : DX

VAR error : WORD);
         AX,CF

    (error = 0 means no error;

               refer to the table in the DOS manual for other errors)
```

Function 3AH: Remove a directory entry (RMDIR)

```
DOSCALL(3AH; stringaddr:ADDRESS; VAR error:WORD);
        AH   DS:DX      AX,CF
```

Function 3BH: Change the current directory (CHDIR)

```
DOSCALL(3BH; stringaddr:ADDRESS; VAR error:WORD);
        AH   DS:DX      AX,CF
```

Function 3CH: Create a File

```
DOSCALL(3CH; stringaddr:ADDRESS; attrib:BYTEWORD;
        AH   DS:DX      CX

VAR handle:BYTEWORD; VAR error:WORD);
        AX      AX,CF
```

Function 3DH: Open a File

```
DOSCALL(3DH; stringaddr:ADDRESS; access:BYTEWORD;
        AH   DS:DX      AL

VAR handle:BYTEWORD; VAR error:WORD);
        AX      AX,CF
```

Function 3EH: Close a file handle

```
DOSCALL(3EH; handle:WORD; VAR error:WORD);
        AH   BX      AX,CF
```

Function 3FH: Read from a file or device

```
DOSCALL(3FH; handle:WORD; nrbytes:WORD;
        AH   BX      CX

buffAddr:ADDRESS;
        DS:DX

VAR readBytes:BYTEWORD;
        AX

VAR error:WORD);
        AX,CF
```

Function 40H: Write to a file or device

```
DOSCALL(40H; handle:WORD; nrbytes:WORD;
        AH   BX      CX

buffAddr:ADDRESS;
        DS:DX

VAR writtenBytes:BYTEWORD; VAR error:WORD);
        AX           AX,CF
```

Function 41H: Delete a file from a specified directory

```
DOSCALL(41H; stringaddr:ADDRESS; VAR error:WORD);
        AH   DS:DX               AX,CF
```

Function 42H: Move file read/write pointer

```
DOSCALL(42H; handle:WORD; method:BYTEWORD;
        AH   BX           AL

inHigh,inLow:WORD;
        CX   DX

VAR outHigh,outLow:WORD; VAR error:WORD);
        DX   AX              AX,CF
```

Function 43H: Change File Mode

```
DOSCALL(43H; stringaddr:ADDRESS; fctcode:BYTEWORD;
        AH   DS:DX               AL

VAR mode:BYTEWORD; VAR error:WORD);
        CX                 AX,CF
```

Function 44H: I/O control for devices

The procedure depends on the value of the second parameter that must be a constant. This parameter determines the function to execute:

Get device info

```
DOSCALL(44H; 0; handle:WORD;
        AH   AL BX

VAR deviceinfo:BYTEWORD;
        DX

VAR error:WORD);
        AX,CF
```

Set device info

```
DOSCALL(44H; 1; handle:WORD;
        AH   AL BX

deviceinfo:BYTEWORD;
        DX

VAR error:WORD);
        AX,CF
```

Read Bytes from device control channel

```
DOSCALL(44H; 2; handle:WORD;
          AH   AL BX

nrBytes:BYTEWORD; buffAddr:ADDRESS;
          CX      DS:DX

VAR transferredbytes:BYTEWORD;
          AX

VAR error:WORD);
          AX,CF
```

Write Bytes to device control channel

```
DOSCALL(44H; 3; handle:WORD;
          AH   AL BX

nrBytes:BYTEWORD; buffAddr:ADDRESS;
          CX      DS:DX

VAR transferedbytes:BYTEWORD;
          AX

VAR error:WORD);
          AX,CF
```

Read Bytes from drive control channel

```
DOSCALL(44H; 4; drive:BYTEWORD;
          AH   AL    BL

nrBytes   : BYTEWORD;
buffAddr  : ADDRESS;
          CX         DS:DX

VAR transferedbytes : BYTEWORD;
          AX

VAR error:WORD);
          AX,CF
```

Write Bytes to drive control channel

```
DOSCALL(44H; 5; drive:BYTEWORD;
          AH   AL      BL

nrBytes:BYTEWORD; buffAddr:ADDRESS;
          CX            DS:DX

VAR transferedbytes:BYTEWORD;
          AX

VAR error:WORD);
          AX,CF
```

Get Input Status

```
DOSCALL(44H; 6; handle: WORD; VAR status:BYTEWORD;
          AH   AL BX          AX

VAR error:WORD);
          AX,CF
```

Get Output Status

```
DOSCALL(44H; 7; handle: WORD; VAR status:BYTEWORD;
          AH   AL BX          AX

VAR error:WORD);
          AX,CF
```

Function 45H: Duplicate a file handle

```
DOSCALL(45H; handle1:WORD; VAR handle2:BYTEWORD;
          AH   BX           AX

VAR error:WORD);
          AX,CF
```

Function 46H: Force a duplicate of a file

```
DOSCALL(46H; handle1:WORD; VAR handle2:BYTEWORD;
          AH   BX           CX

VAR error:WORD);
          AX,CF
```

Function 47H: Get Current Directory

```
DOSCALL(47H; drive:BYTEWORD; straddr:ADDRESS;
          AH   DL           DS:SI

VAR error:WORD);
          AX,CF
```

Function 48H: Allocate Memory

```
DOSCALL(48H; VAR paragraphs:BYTEWORD;
          AH   BX

VAR membase:BYTEWORD;
          AX

VAR error:WORD);
          AX,CF
```

Function 49H: Free allocated Memory

```
DOSCALL(49H: segaddr:ADDRESS;
          AH   ES must be a paragraph address

VAR error:WORD);
          AX,CF
```

Function 4AH: SETBLOCK-Modify allocated memory blocks

```
DOSCALL(4AH; blockaddr:ADDRESS;
          AH   ES must be a paragraph address

VAR paragraphs:BYTEWORD;
          BX

VAR error:WORD);
          AX,CF
```

Function 4BH: Load or execute a program

```
DOSCALL (4BH;stringaddr : ADDRESS;
             paramblock : ADDRESS;
          AH   DS : DX   ES:BX

fctval : BYTEWORD;
          AL

VAR error : WORD);
          AX,CF
```

Function 4CH: Terminate a process(Exit)

```
DOSCALL(4CH; returnCode:BYTEWORD);
          AH   AL
```

Function 4DH: Retrieve the return code of a sub-process(Wait)

```
DOSCALL(4DH; VAR retCode:BYTEWORD);
          AH   AX
```

Function 4EH: Find first matching file

```
DOSCALL(4EH; stringaddr:ADDRESS; attribut:BYTEWORD;
          AH   DS:DX      CX

VAR error:WORD);
          AX,CF
```

Function 4FH: Find next matching file

```
DOSCALL(4FH; VAR error:WORD);
          AH      AX,CF
```

Function 54H: Get Verify state

```
DOSCALL(54H; VAR state:BYTE);
          AH      AL
```

Function 56H: Rename a file

```
DOSCALL(56H; fromstring,tostring:ADDRESS;
          AH   DS : DX      ES : DI

VAR error:WORD);
           AX, CF
```

Function 57H: Get/Set a file's date and time

```
DOSCALL(57H; handle : WORD;
               mode : BYTEWORD;
         AH    BX       AL

VAR date,time : BYTEWORD;
         DX    CX

VAR error     : WORD);
         AX, CF
```

8.4 Decimals

The module **Decimals** provides functions for arithmetic and formatting with decimal numbers of 18 or less digits. These functions are appropriate for business-oriented computation.

8.4.1 Internal and External Format

Decimal numbers have two formats -- external and internal. Numbers in external format are represented by character strings. This external format is used for reading and writing numbers to the console or printer in a form you can understand. Arithmetic operations are performed on numbers stored in an encoded, internal format. The procedures **StrToDec** and **DecToStr** convert decimal numbers between internal and external format. **StrToDec** encodes decimal numbers and **DecToStr** decodes decimal numbers.

8.4.2 Types

Module **Decimals** provides the following types:

DECIMAL

Used for internal representation of a decimal number. Arithmetic operations are performed on variables of type **DECIMAL**.

DecState

A variable of type **DECIMAL** has a state of type **DecState** associated with it. This state may have the following values:

NegOvfl	indicates negative overflow
Minus	indicates negative decimal value
Zero	indicates value **0**
Plus	indicates positive decimal value
PosOvfl	indicates positive overflow
Invalid	indicates invalid number

The procedure **DecStatus** returns the state of a decimal variable.

8.4.3 Variables

The following variables are exported from module **Decimals**:

DecValid

Indicates the success of the last operations. **DecValid** is set after each call to a conversion or arithmetic procedure. It is set to **FALSE** if the operation failed.

Remainder

Remainder is set after each division operation with procedure **DivDec**. **DivDec** returns an integer number for the quotient. If the result is not an integer number, **Remainder** indicates the first digit that appears after the decimal point. For example, the division of 39 by 8 yields a quotient of 4. The remainder is equal to 8 because this digit appears immediately after the decimal point in the exact result of 4.875. If the division operation fails, the remainder is '**?**'.

8.4.4 Conversion and Status Procedures

The following conversion and status procedures are provided by module **Decimals**:

StrToDec

Converts numbers from external to internal format. (Explained in greater detail below.)

DecToStr

Converts numbers from internal to external format. (Explained in greater detail below.)

DecStatus

Returns the current state of a decimal variable. **DecStatus** can be used to get the sign of a valid decimal number. When an operation fails, you can call the procedure **DecStatus** to determine the actual arithmetic error. **DecStatus** specifies the error status of the decimal variable according to type **DecState**.

8.4.5 Arithmetic Operations

The following arithmetic operations can be performed with variables of type **DECIMAL**:

CompareDec	Compares two decimal values, **Dec0** and **Decl**. Output is an integer value as follows: **1** if **Dec0** is greater than **Decl** **0** if **Dec0** equals **Decl** **-1** if **Dec0** is less than **Decl**
AddDec	Adds two decimal values, **Dec0** and **Decl**. The output is the sum of the two values, a decimal value.
SubDec	Performs the subtraction of one decimal value, **Decl**, from another decimal value, **Dec0**. The output is the difference of the two values, a decimal value.
MulDec	Performs the multiplication of two decimal values, a multiplicand, Dec0 and a multiplier, Dec1. The output is the product of the two values, a decimal value.
DivDec	Performs the division of one decimal value by another. The dividend, **Dec0** is divided by the divisor, **Decl**. Output is the quotient of the two values, a decimal value. The remainder is placed in the global variable **Remainder** as previously explained.
NegDec	Returns the negative value of a decimal value.

8.4.6 Pictures

Numbers in external format are stored in character strings. These strings may include a currency character, commas and decimal points. For example:

```
$923,841,371.38
```

is a decimal number in external format.

So called "pictures" are used for the conversion between the string representation of decimal numbers in external format and their representation in internal format. Pictures indicate how decimal numbers appear in external format. They control the occurrence of leading blanks, leading zeros, number signs, currency characters, commas and decimal points.

For example, the picture which corresponds to the decimal number shown above is:

```
$,$$$,$$$,$$$,$$9.99
```

With the picture **ZZZZZZZZZZZZ9** the same decimal number would have appeared as:

```
92384137138
```

8.4.7 Picture Characters

Blank spaces may not appear in a picture. Pictures may consist of the following characters only:

9	digit
Z	nonzero digit or leading blank
$	nonzero digit, leading blank, or **$**
S	sign of number (+ or -)
.	decimal point
,	comma or leading blank

If the first character of a picture is a dollar sign (**$**), it will appear as a currency character in the external format. The currency character floats across any leading blanks so it appears adjacent to the leftmost digit. However, if a decimal value consists of the same number of digits as the picture which represents it, each dollar sign will be replaced by a digit and thus, no currency character will appear.

Numbers without leading zeros are represented with '**Z**'s. '**Z**' is replaced by a digit if there is one, otherwise it is replaced by a blank.

'**9**'s represent numbers which require leading zeros to be displayed. A '**9**' is replaced by a digit if there is one, otherwise it is replaced by a zero.

In the following picture, the '**9**'s guarantee that dollar amounts less than **$1.00** appear in standard form.

```
$$$,$$9.99
```

The following numbers correspond to this picture:

```
     $0.39
   $369.00
$48,327.04
```

Sign characters (**S**) and decimal points (**.**) do not float across leading blanks, they appear in their specified position. Commas (**,**), '**Z**' and **$** characters correspond to leading blanks when they appear to the left of a number.

8.4.8 Procedure StrToDec

The procedure **StrToDec** uses pictures to convert numbers from external to internal format. If the input string is shorter than the picture string, leading blanks are added until it is the same length as the picture. A currency character can appear only once in the input string, and it must be adjacent to the leftmost digit. Commas are matched if they are within the number, or ignored if they appear to the left of the number. The sign character is matched by a '+', '-' or a blank. Decimal points are matched unconditionally.

Pictures ensure that input strings will be within a limited range. **StrToDec** sets **DecValid** to **FALSE** and the state of the decimal result to **Invalid** under the following conditions:

- The input string does not match the picture specification.
- The input string is longer than the picture string.
- The input string and the picture specify more than 18 digits.

8.4.9 Procedure DecToStr

If the number of digits in a number in external format exceeds the number of digit characters in the picture which represents it, **DecToStr** sets **DecValid** to **FALSE** and returns an **invalid** format string. Thus, pictures can be used to control the maximum number of digits that can appear in a number.

Procedure **DecToStr** represents erroneous decimal variables with special character strings depending on the state of the decimal variable:

PosOvfl	is represented by	+ + + + + + +
NegOvfl	is represented by	- - - - - - -
Invalid	is represented by	? ? ? ? ? ? ?

The length of the string is determined by the length of the corresponding picture.

8.4.10 Error Propagation

Once an error occurs in a decimal variable as the result of an operation, the error remains through all the operations involving the variable. The following tables show how errors are propagated by the arithmetic operations. For operations in the form A <operation> B, the leftmost column represents states of A and the topmost row represents states of B.

ADDITION and SUBTRACTION

A/B	NegOvfl	Minus	Zero	Plus	PosOvfl	Invalid
NegOvfl	NegOvfl	NegOvfl	NegOvfl	NegOvfl	Invalid	Invalid
Minus	NegOvfl				PosOvfl	Invalid
Zero	NegOvfl				PosOvfl	Invalid
Plus	NegOvfl				PosOvfl	Invalid
PosOvfl	Invalid	PosOvfl	PosOvfl	PosOvfl	PosOvfl	Invalid
Invalid	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid

MULTIPLICATION

A/B	NegOvfl	Minus	Zero	Plus	PosOvfl	Invalid
NegOvfl	PosOvfl	PosOvfl	Zero	NegOvfl	NegOvfl	Invalid
Minus	PosOvfl	Plus	Zero	Minus	NegOvfl	Invalid
Zero	Zero	Zero	Zero	Zero	Zero	Invalid
Plus	NegOvfl	Minus	Zero	Plus	PosOvfl	Invalid
PosOvfl	NegOvfl	NegOvfl	Zero	PosOvfl	PosOvfl	Invalid
Invalid	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid

DIVISION

A/B	NegOvfl	Minus	Zero	Plus	PosOvfl	Invalid
NegOvfl	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
Minus	Invalid	Plus	Invalid	Minus	Invalid	Invalid
Zero	Zero	Zero	Invalid	Zero	Zero	Invalid
Plus	Invalid	Minus	Invalid	Plus	Invalid	Invalid
PosOvfl	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid
Invalid	Invalid	Invalid	Invalid	Invalid	Invalid	Invalid

8.5 REAL Arithmetic

Modula-2 provides the data type **REAL** for floating point arithmetic. *LOGITECH Modula-2* supports the type **REAL** according to the IEEE standard for double precision floating point numbers. This format uses **8** bytes and is precise for **15** to **16** decimal digits. The values that can be represented range from **2.23** times **10** to the minus **308**th power, to **1.79** times **10** to the **308**th power:

```
        2.23E-308 <= |x| <= 1.79E+308.
```

An optional *8087* math coprocessor can be added to many *8086/8088* based microcomputer systems. The *8087* performs floating point operations at very high speed. It provides a set of instructions which manipulate operands and yield results in the IEEE standard floating point format. If an *8087* coprocessor is not present, the **REAL** arithmetic functions must be emulated on the *8086* or *8088* processor.

LOGITECH Modula-2 allows you to create programs that use an *8087* coprocessor and run at very high speed, as well as programs that emulate **REAL** arithmetic on the *8086* or *8088*. A compile time switch decides whether the compiler generates *8087* inline code or code that uses the ***LOGITECH REAL Arithmetic Emulator***.

8.5.1 Simple Use of REAL Arithmetic

If you know your program will be running on a system with an *8087*, you can use the compiler option Coprocessor. When compiling with the Coprocessor option, the compiler generates *8087* inline code for REAL operations. The library file C87LIB.LIB contains those ***LOGITECH Modula-2*** library modules with *8087* inline code. If you compile with the Coprocessor option you should use these files when linking. A program that includes *8087* inline code requires an *8087* to run and cannot be executed on a system without an *8087*.

The following describes the easiest way to create a program that runs without an *8087* coprocessor:

You must choose the compiler option Emulator if your program should run on a system without an *8087*. When compiling with the Emulator option, which is the default, the compiler generates code for the ***LOGITECH REAL*** emulator. It also generates a reference to module Reals and to M2REAL.LIB which provides the REAL emulation. The library file E87LIB.LIB contains those ***LOGITECH Modula-2*** library modules that have been compiled for the emulator. If you compile with the Emulator option you should use these files when linking. When you link with the files from E87LIB.LIB, your program will always use the emulator for REAL arithmetic.

A ***LOGITECH Modula-2*** program compiled with the Emulator option can also be linked so that it uses an *8087* for execution and executes at maximum speed. It is also possible to link the program such that it uses an *8087* if one is present, and otherwise uses the emulator. The library M87LIB.LIB contains two versions of the library modules.

8.5.2 Choices for Using REAL Arithmetic

You may decide what kind of REAL arithmetic to use, either at compile-time, link-time or run-time.

The later the decision about which kind of REAL arithmetic to use is made, the more the portability of a program is improved. However, postponing this decision also increases memory requirements and decreases execution speed. The relative benefits and disadvantages of each alternative are detailed below.

LOGITECH Modula-2 offers the following alternatives for REAL arithmetic:

- At compile time the compiler options Coprocessor and Emulator determine the kind of code generated. Choose to generate *8087* inline code (Coprocessor option) or to compile for the *LOGITECH REAL* emulator (Emulator option). When compiling for the emulator, the compiler automatically generates a reference to the module **Reals** and to M2LIB.LIB which provides the REAL emulation. The compiler implicitly knows the interface of module **Reals**, therefore no symbol file needs to be provided.

- To generate *8087* inline code, an *8087* coprocessor is required to execute the program. The program will not run on a system without an *8087*.

- If you choose to compile a module for the ***LOGITECH REAL emulator***, how the program will be linked is still flexible. *LOGITECH Modula-2* provides the following implementations for the REAL emulator (module **Reals**) and for the mathematical functions (module **MathLib0**):

  - If the program will not be executed on a system with an *8087*, using the pure emulator version is the best choice. To use this version of the emulator, you must link with the files with E87LIB.LIB. A program linked in this way may be executed on a system with an *8087*; however, it will never use the *8087*.

  - The pure *8087* version of the emulator can be useful if the program being linked is executed on a system with an *8087*. To use this version of the emulator, you should link with the files from C87LIB.LIB. A program linked with these files requires an *8087* for execution.

- Using a "mixed" version of the emulator postpones, until run-time, the decision of whether or not to use an *8087*. The mixed emulator version is a combination of the other two versions, and thus is the most flexible option. If you choose to link with the mixed version of the emulator, then it will be determined at run-time whether an *8087* is present or not. Based on this determination:

- The program will use the *8087* if executed on a system with an *8087*.

- The program will use the emulator to perform REAL arithmetic when the *8087* coprocessor is not present.

- Linking with the mixed version of the emulator increases flexibility and improves the portability of a program. The main disadvantage of the mixed version of the emulator is that the program requires more memory to run because the code for both forms of the emulation must be present. When linking the program, the M87LIB library file must be used.

The distribution diskettes contain all three of the above-mentioned libraries with the emulator version E87LIB.LIB as the default, since it has been copied to M2REAL.LIB. Thus when you use the compiler and the linker with the default options, the LOGITECH REAL Arithmetic Emulator will be used.

M2REAL.LIB contains the following modules of the ***LOGITECH Modula-2 Library.***

Reals	The ***LOGITECH Real Arithmetic Emulator***
MathLib0	

These two modules are differently implemented in each version of M2REAL.LIB.

E87LIB.LIB	Contains emulator code
C87LIB.LIB	Contains *8087* code
M87LIB.LIB	Has both emulator and 8087 code, triggered by a switch that indicates teh presence of the mathematical co-processor.

RealConversions

RealInOut

FloatingUtilities

Random

DurationOps

These are those modules that use the type **REAL.** They all have some implementation, but are compiled with different options.

E87LIB.LIB	use option	/E
C87LIB.LIB	use option	/C
M87LIB.LIB	use option	/E

1) For 8087 Inline Code

Copy the library C87LIB.LIB onto M2REAL.LIB

Compile all your modules which use floating point arithmetic with the **/C** option.

2) For The Pure Emulator

Copy the library E87LIB.LIB onto M2REAL.LIB

Compile all your modules which use floating point arithmetic with the **/E** option.

3) For the 8087 Version of the Emulator

Copy the library C87LIB.LIB onto M2REAL.LIB

Compile all your modules which use floating point arithmetic with the **/E** option.

4) For the Mixed Emulator

Copy the library M87LIB.LIB onto M2REAL.LIB

Compile all your modules which use floating point arithmetic with the **/E** option.

The difference between 1) and 3) is that in 1) the module Real is not referenced or used, since the code has been generated inline.

8.5.3 Accuracy of the Computations

For all the basic arithmetic operations on operands of type **REAL**, the *8087* coprocessor and the ***LOGITECH REAL Emulator*** yield the same results. To compute mathematical functions such as sine or cosine, the emulator uses the Chebyshev polynomial approximation. Because the *8087* coprocessor uses a different scheme for approximation, the results of mathematical functions may sometimes differ slightly. For all practical purposes, these differences between the *8087* and the emulator are not significant.

8.5.4 Memory Requirements

When you compile with the Coprocessor option, the compiler generates *8087* inline code and makes no reference to the emulator (module **Reals**). Module **Reals** is only linked into a program if some part of the program was compiled using the Emulator option. As a general rule, the memory requirements are larger for programs that use the emulator.

Table 8-1 lists the approximate memory requirements (code and data) for the different implementations of the modules **Reals** and **MathLib0**. All numbers are given in bytes.

	Reals	**MathLib0**	**Reals and MathLib0**
8087 Inline Code	---	1700	1700
8087 Version of Emulator	500	1700	2200
Pure Emulator	2300	4200	6500
Mixed Emulator	2800	6100	8900

Table 8-1

8.5.5 Performance

Table 8-2 lists the time measured for 1000 executions of the addition, multiplication, and division of two **REAL** numbers. Subtraction and addition require the same amount of time. The last row lists the times measured for 1000 executions of a loop that performs once, each basic operation (addition, subtraction, etc.), each kind of comparison (equal, less than, etc.), and calls once, each of the functions provided by **MathLib0**.

All times are given in seconds. However, the times measured may differ from system to system. Table 8-2 allows for a relative comparison of the performance you can expect when choosing a particular alternative for **REAL** arithmetic in *LOGITECH Modula-2*. On the average, *8087* inline code is approximately ten times faster than full emulation of **REAL** arithmetic on the *8086*.

	Addition	Multiplication	Division	Combination
Pure Emulator	1.0	1.2	2.1	61.0
8087 Inline Code	0.11	0.11	0.11	6.6
8087 Version of Emulator	0.22	0.22	0.22	8.2
Mixed Emulator (with 8087)	0.31	0.31	0.31	12.5
Mixed Emulator (without 8087)	1.1	1.3	2.2	63.0

Table 8-2

8.6 RTS

LOGITECH Modula-2 Run-Time Support provides support to the application for error handling, arithmetic coprocessor use, interrupt handling, and language dependent facilities.

8.6.1 Organization

The main module of the *RTS* is **RTSMain**, which must always be linked to the application. Other modules of the *RTS* may be linked or not, depending on their needs.

Module	Function
RTSMain	Entrypoint Initialization
RTSError **RTSRealError**	Error Checks
RTSLanguage	Special Language Constructs Support
RTSCoroutine **RTSInterrupt** **RTSPriority**	Interrupt and Process Management
RTSDevice **RTSIntProc**	I/O Device Control
RTS87 **RTSM87**	Math Coprocessor Support

8.6.2 RTSMain

RTSMain is the entry point of any ***LOGITECH Modula-2*** application. It initializes the run-time support, and then gives control to the application.

8.6.3 RTSError

The **RTSError** module will be present if run-time checks (e.g., range error checks) are requested at compile time. It provides an entry point for the different kinds of error. This module has also the task, in case of run-time error, of clearing the stack. **RTSRealError** does the same if **REAL** type is used.

8.6.4 Language Dependent Facilities

The **RTSLanguage** module provides the routines that are called in the case of dynamic parameter **copy**, (e.g.,. a parameter of type **ARRAY OF CHAR**). This module provides also support for special cases of **CASE** statements.

8.6.5 Interrupt Handling

The **RTSPriority** module is used if some modules of the application are priority modules. It provides routines to change and restore the priority mask of the application when a procedure is called that belongs to a priority module.

The **RTSInterrupt** module is needed when binding a multiprocess application. An **IOTRANSFER** call will refer to this module.

8.6.6 I/O Device Control

RTSDevice and **RTSIntPROC** let you get control on the processors interrupt vector. They also let you change and restore such vectors.

8.6.7 Arithmetic Coprocessors

RTS87 or **RTSM87** provide support for the *80n87* arithmetic coprocessor.

RTS87 will be needed is some modules of the application have been compiled with the **/C** switch (for coprocessor use).

RTSM87 is used in the mixed Emulator/Coprocessor mode.

8.7 Graphics

The *LOGITECH Modula-2* library provides a graphics module **Graphics**. This module is provided with different implementations, depending on the graphics you want to use.

Currently the following adaptors are supported:

CGA	GRAPHCGA.OBJ
Hercules	GRAPHHEC.OBJ

By default, GRAPHCGA.OBJ is copied onto GRAPHICS.OBJ. These object files are not part of any library, but are distributed as .OBJ files.

Chapter 9
Libraries

9.1 Library Search Strategy

The *LOGITECH Modula-2 Compiler, Linker, Debuggers* and the other *Utilities* automatically search for all referenced modules. The default search strategy can be modified by command options.

The following discussion uses **PATH** or **PATHNAME** as a synonym for **drive** and/or **pathname.** For example, **C:\M2LIB\SYM** is the **PATHNAME** for the file C:\M2LIB\SYM\STORAGE.SYM.

9.1.1 Default Names

The *LOGITECH Modula-2 Compiler, Linker, Debuggers, M2MAKE, M2CHECK* and *M2DECODE* construct default filename from module names. This is done by truncating the module name to the length of a *DOS* file name, and appending the appropriate extension (.SYM, .OBJ, etc.) to that name. This default filename is then used to find the corresponding file on all paths that are defined by the search strategy.

9.1.2 The Default Search Strategy

When a module is needed, several paths will be checked automatically to find the corresponding file. The search strategy, as described below, is applied by all *LOGITECH Modula-2 Utilities* that look for referenced modules.

- Since all utilities per default generate their output files into the current directory, the currrent directory is the first path used to find the needed file.
- If the file was not found in the current directory, the so-called **master path** is used to find the file. The master path is the path where the main (or master) input module for the currently executed utility comes from.
- If the file was not found in the master path, those paths defined by the environment variables are taken one after the other to look for the file. The environment variables are set by the user after his own fashion. A default setting for the default installation of the *LOGITECH Modula-2 System* has been provided:

```
SET M2SYM=\M2LIB\SYM
SET M2OBJ=\M2LIB\OBJ
SET M2REF=\M2LIB\REF
SET M2MAP=\M2LIB\MAP
SET M2LIB=\M2LIB\LIB
SET M2MOD=\M2LIB\MOD
SET M2DEF=\M2LIB\DEF
```

  Each of these environment strings can denote a number of paths, separated by semicolons.

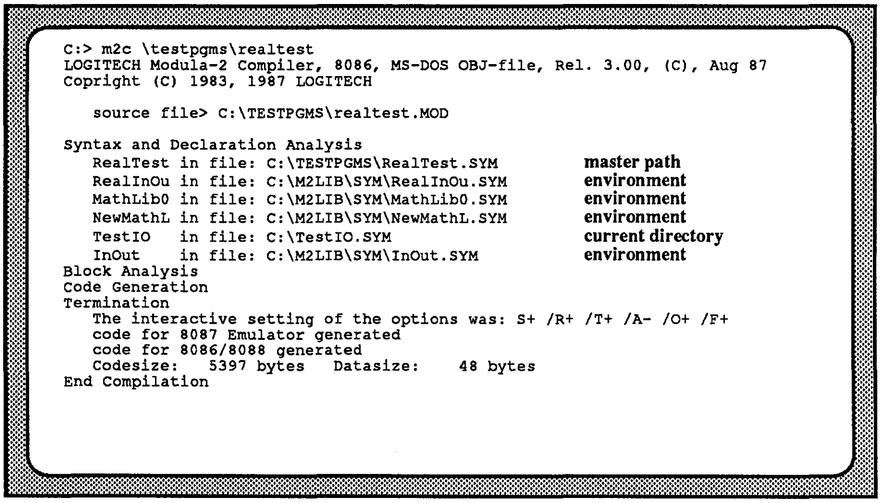
If the needed file was not found on one of the defined paths, the default search strategy will take effect.

Assume the following environment settings:

```
SET M2SYM=\M2LIB\SYM;\MYLIB\SYM
SET M2OBJ=\M2LIB\OBJ;\MYLIB\OBJ
SET M2REF=\M2LIB\REF;\MYLIB\REF;
SET M2MAP=\M2LIB\MAP;\MYLIB\MAP;
SET M2LIB=\M2LIB\LIB;\MYLIB\LIB;
SET M2MOD=\M2LIB\MOD;\MYLIB\MOD;
SET M2DEF=\M2LIB\DEF;\MYLIB\DEF;
```

Calling the compiler with the following command will automatically take the indicated symbol files as input:

M2C \TESTPGMS\REALTEST ↵



```
C:> m2c \testpgms\realtest
LOGITECH Modula-2 Compiler, 8086, MS-DOS OBJ-file, Rel. 3.00, (C), Aug 87
Copright (C) 1983, 1987 LOGITECH

   source file> C:\TESTPGMS\realtest.MOD

Syntax and Declaration Analysis
   RealTest in file: C:\TESTPGMS\RealTest.SYM         master path
   RealInOu in file: C:\M2LIB\SYM\RealInOu.SYM        environment
   MathLib0 in file: C:\M2LIB\SYM\MathLib0.SYM        environment
   NewMathL in file: C:\M2LIB\SYM\NewMathL.SYM        environment
   TestIO   in file: C:\TestIO.SYM                    current directory
   InOut    in file: C:\M2LIB\SYM\InOut.SYM           environment
Block Analysis
Code Generation
Termination
   The interactive setting of the options was: S+ /R+ /T+ /A- /O+ /F+
   code for 8087 Emulator generated
   code for 8086/8088 generated
   Codesize:   5397 bytes   Datasize:    48 bytes
End Compilation
```

9.1.3 The Query Search Strategy

The query search strategy is always applied by the ***LOGITECH Modula-2*** system when you are prompted to type in the (path and) file name of a library file. This can happen when a file is not found using the default search strategy, or when you specify the Query option when compiling.

When you see a prompt on the ***LOGITECH Modula-2 Compiler*** screen, several responses are available.

What You Enter	**What It Means**
Esc	Means "no file". Use this to indicate that the file is not available. Depending on context, Esc may not let you complete the program.
↵	Means the FILENAME should be constructed from the module name, and that the default search strategy (as explained above) will be applied.
FILENAME **only**	**(no** PATH **name)** The FILENAME will be used, but will still be searched for automatically according to the default search strategy.
PATH NAME **only ended by : or \**	The file name will be constructed from the module name, and searched for using the specified path. Only one attempt to open the file will be made.
Complete PATH **and** FILENAME.	Here too, only one attempt will be made to open the file.

9.2 Library .DEF Files

ASCII

```
DEFINITION MODULE ASCII;
(*
   Symbolic constants for non-printing ASCII characters.
   This module has an empty implementation.
*)

EXPORT QUALIFIED
   nul, soh, stx, etx, eot, enq, ack, bel,
   bs,  ht,  lf,  vt,  ff,  cr,  so,  si,
   dle, dc1, dc2, dc3, dc4, nak, syn, etb,
   can, em,  sub, esc, fs,  gs,  rs,  us,
   del,
   EOL;

CONST
   nul = 00C;     soh = 01C;  stx = 02C;    etx = 03C;
   eot = 04C;     enq = 05C;  ack = 06C;    bel = 07C;
   bs  = 10C;     ht  = 11C;  lf   = 12C;   vt  = 13C;
   ff  = 14C;     cr  = 15C;  so   = 16C;   si  = 17C;
   dle = 20C;     dc1 = 21C;  dc2 = 22C;    dc3 = 23C;
   dc4 = 24C;     nak = 25C;  syn = 26C;    etb = 27C;
   can = 30C;     em  = 31C;  sub = 32C;    esc = 33C;
   fs  = 34C;     gs  = 35C;  rs   = 36C;   us  = 37C;
   del = 177C;

CONST
   EOL = 36C;
   (*
   - end-of line character

   This (non-ASCII) constant defines the internal name of the end-of-line character.
   Using this constant has the advantage, that only one character is used to specify
   line ends (as opposed to cr/lf).

   The standard I/O modules interpret this character and transform it into the
   (sequence of) end-of-line code(s) required by the device they support.  See
   definition modules of 'Terminal' and 'FileSystem'.
   *)

END ASCII.
```

BitBlockOps

```
DEFINITION MODULE BitBlockOps;

(* Bitwise operations on blocks.
   Blocks are defined as a starting address and a size, i.e. the number of
   bytes they hold.
   In a block, the left or low bit is the low bit of the byte located
    at (starting address); and the right or high bit is the high bit of the byte
   located at (starting address + size - 1)
*)

FROM SYSTEM IMPORT ADDRESS;

  PROCEDURE BlockAnd (destination, source: ADDRESS;
                      size               : CARDINAL);
    (* ANDs the block destination with the block source   *)

  PROCEDURE BlockOr  (destination, source: ADDRESS;
                      size               : CARDINAL);
    (* Bitwise OR *)

  PROCEDURE BlockXor (destination, source: ADDRESS;
                      size               : CARDINAL);
    (* Bitwise XOR *)

  PROCEDURE BlockNot (block : ADDRESS;
                      size  : CARDINAL);
    (* Bitwise complement to 1 *)

  PROCEDURE BlockShr (block : ADDRESS;
                      size  : CARDINAL;
                      count : CARDINAL);
    (* Shift Logical Right
       shifts the bits in block to the right by the number of bits specified
       in count.  Zeros are shifted in on the left. *)

  PROCEDURE BlockSar (block : ADDRESS;
                      size  : CARDINAL;
                      count : CARDINAL);
    (* Shift Arithmetic Right
       shifts the bits in block to the right by the number of bits specified
       in count.   Bits equal to the original high order bit are shifted in
       on the left, preserving the sign of the original value. *)

  PROCEDURE BlockShl (block : ADDRESS;
                      size  : CARDINAL;
                      count : CARDINAL);
    (* Shift Left
       shifts the bits in block to the left by the number of bits specified
       in count.  Zeros are shifted in on the right. *)

  PROCEDURE BlockRor (block : ADDRESS;
                      size  : CARDINAL;
                      count : CARDINAL);
    (* Rotate Right
       rotates block right by the number of bits specified in count *)
  PROCEDURE BlockRol (block : ADDRESS;
                      size  : CARDINAL;
                      count : CARDINAL);
    (* Rotate Left
       rotates block left by the number of bits specified in count *)

END BitBlockOps.
```

BitByteOps

```
DEFINITION MODULE BitByteOps;

  (* Bitwise operations on bytes.
     Bits in bytes are numbered from 0 to 7 *)

  FROM SYSTEM IMPORT BYTE;

  PROCEDURE GetBits (source           : BYTE;
                     firstBit, lastBit : CARDINAL): BYTE;
    (* Extracts the bits of source from firstBit to lastBit and returns them
       as a byte in which bit 0 correspond to the firstBit of the source.
    *)

  PROCEDURE SetBits (VAR byte         : BYTE;
                     firstBit, lastBit: CARDINAL;
                     pattern          : BYTE);
    (* Masks byte with pattern from firstBit to lastBit.  The first
       (lastBit - firstBit + 1 of pattern are used, with leading zeros if necessary.
       Examples : To set the bits to 1, the pattern 0FFH should be passed,
                  and to set the bits to 0, the pattern 0 should be passed.
    *)

  PROCEDURE ByteAnd (left, right : BYTE): BYTE;
    (* Bitwise AND *)

  PROCEDURE ByteOr  (left, right : BYTE): BYTE;
    (* Bitwise OR *)

  PROCEDURE ByteXor (left, right : BYTE): BYTE;
    (* Bitwise XOR *)

  PROCEDURE ByteNot (byte : BYTE): BYTE;
    (* Bitwise complement to 1 *)

  PROCEDURE ByteShr (byte  : BYTE;
                     count : CARDINAL): BYTE;
    (* Shift Logical Right
       shifts the bits in byte to the right by the number of bits specified in count.
       Zeros are shifted in on the left. *)

  PROCEDURE ByteSar (byte  : BYTE;
                     count : CARDINAL): BYTE;
    (* Shift Arithmetic Right
       shifts the bits in byte to the right by the number of bits specified in count.
       Bits equal to the original high order bit are shifted in on the left,
       preserving the sign of the original value.
    *)

  PROCEDURE ByteShl (byte  : BYTE;
                     count : CARDINAL): BYTE;
    (* Shift Left
       shifts the bits in byte to the left by the number of bits specified in count.
       Zeros are shifted in on the right. *)
  PROCEDURE ByteRor (byte  : BYTE;
                     count : CARDINAL): BYTE;
    (* Rotate Right
       rotates byte right by the number of bits specified in count *)

  PROCEDURE ByteRol (byte  : BYTE;
                     count : CARDINAL): BYTE;
    (* Rotate Left
       rotates byte left by the number of bits specified in count *)

  PROCEDURE HighNibble (byte : BYTE): BYTE;
    (* Returns the high order nibble (4 bits) value of byte *)

  PROCEDURE LowNibble (byte : BYTE): BYTE;
    (* Returns the low order nibble (4 bits) value of byte *)

  PROCEDURE Swap (VAR byte : BYTE);
    (* Swaps the high and low order nibble values of byte *)

END BitByteOps.
```

BitWordOps

```
DEFINITION MODULE BitWordOps;

  (* Bitwise operations on words.
     Bits in words are numbered from 0 to 15 *)

  FROM SYSTEM IMPORT WORD;

  PROCEDURE GetBits (source            : WORD;
                     firstBit, lastBit : CARDINAL): WORD;
    (* Extracts the bits of source from firstBit to lastBit and returns them
       as a word in which bit 0 correspond to the firstBit of the source.
    *)

  PROCEDURE SetBits (VAR word         : WORD;
                     firstBit, lastBit: CARDINAL;
                     pattern          : WORD);
    (* Masks word with pattern from firstBit to lastBit.  The first
       (lastBit - firstBit + 1 of pattern are used, with leading zeros
       if necessary.
       Examples : To set the bits to 1, the pattern 0FFFFH should be passed,
       and to set the bits to 0, the pattern 0 should be passed. *)

  PROCEDURE WordAnd (left, right : WORD): WORD;
    (* Bitwise AND *)

  PROCEDURE WordOr  (left, right : WORD): WORD;
    (* Bitwise OR *)

  PROCEDURE WordXor (left, right : WORD): WORD;
    (* Bitwise XOR *)

  PROCEDURE WordNot (word : WORD): WORD;
    (* Bitwise complement to 1 *)

  PROCEDURE WordShr (word  : WORD;
                     count : CARDINAL): WORD;
    (* Shift Logical Right
       shifts the bits in word to the right by the number of bits specified
       in count.  Zeros are shifted in on the left. *)

  PROCEDURE WordSar (word  : WORD;
                     count : CARDINAL): WORD;
    (* Shift Arithmetic Right
       shifts the bits in word to the right by the number of bits specified in count.
       Bits equal to the original high order bit are shifted in on the left,
       preserving the sign of the original value.
    *)

  PROCEDURE WordShl (word  : WORD;
                     count : CARDINAL): WORD;
    (* Shift Left
       shifts the bits in word to the left by the number of bits specified in count.
       Zeros are shifted in on the right.
    *)
  PROCEDURE WordRor (word  : WORD;
                     count : CARDINAL): WORD;
    (* Rotate Right
       rotates word right by the number of bits specified in count *)

  PROCEDURE WordRol (word  : WORD;
                     count : CARDINAL): WORD;
    (* Rotate Left
       rotates word left by the number of bits specified in count *)

  PROCEDURE HighByte (word : WORD): WORD;
    (* Returns the high order byte value of word *)

  PROCEDURE LowByte (word : WORD): WORD;
    (* Returns the low order byte value of word *)

  PROCEDURE Swap (VAR word : WORD);
    (* Swaps the high and low order bytes value of word *)

END BitWordOps.
```

BlockOps

```
DEFINITION MODULE BlockOps;

  (* Block operations.
     Blocks are defined with a starting address and a size, i.e. the number
     of bytes they contain.
   *)

  FROM SYSTEM IMPORT ADDRESS;

  PROCEDURE BlockMoveForward (destination, source : ADDRESS;
                              size                : CARDINAL);
    (* Moves size bytes from source to destination, starting at the address
       of source and going up until address of (source+size) is reached *)

  PROCEDURE BlockMoveBackward (destination, source : ADDRESS;
                               size                : CARDINAL);
    (* Moves size bytes from source to destination, starting at (source+size)
       and going down until address of source is reached *)

  PROCEDURE BlockMove (destination, source : ADDRESS;
                       size                : CARDINAL);
    (* Moves size bytes from source to destination, test is made on the
       addresses of source and destination to decide whether MoveBackward or
       MoveForward is to be used.  Note that because of this comparison,
       Move is slightly slower than the two previous procedures *)

  PROCEDURE BlockClear (block : ADDRESS;
                        size  : CARDINAL);
    (* Fills size bytes with 0, starting from block. *)

  PROCEDURE BlockSet (block       : ADDRESS;
                      blockSize   : CARDINAL;
                      pattern     : ADDRESS;
                      patternSize : CARDINAL);
    (* Fills blockSize bytes starting from block with the pattern of
       patternSize bytes. *)

  PROCEDURE BlockEqual (block1, block2 : ADDRESS;
                        size           : CARDINAL): BOOLEAN;
    (* Returns TRUE if the blocks starting at left and right have the same
       first size bytes. *)

  PROCEDURE BlockPosition (block       : ADDRESS;
                           blockSize   : CARDINAL;
                           pattern     : ADDRESS;
                           patternSize : CARDINAL): CARDINAL;
    (* Searches pattern in block, returns the index of the first successful
       match, MaxCard if no match. *)

END BlockOps.
```

Break

```
DEFINITION MODULE Break;
(*
   Handling of the Ctrl-Break interrupt

   This module provides an interrupt handler for the Ctrl-Break interrupt 1BH of
   MS-DOS and PC-DOS on the IBM-PC.  This module depends on the ROM BIOS of the
   IBM-PC and will not run on any machine which is not compatible to an IBM-PC at
   this level.

   Module 'Break' installs a default break handler, which stops the execution of the
   current program with 'System.Terminate(stopped)' when Ctrl-Break is typed.  This
   produces a memory dump for the stopped program.

   Module 'Break' allows a program to install its own break handler, and to enable or
   disable the break handler which is currently installed.
*)

EXPORT QUALIFIED
   EnableBreak, DisableBreak, InstallBreak, UnInstallBreak;

PROCEDURE EnableBreak;
(*
   - Enable the activation of the current break handler
     If Ctrl-Break is detected, the currently installed break handler will be called.
*)

PROCEDURE DisableBreak;
(*
   - Disable the activation of the current break handler
     If a Ctrl-Break is detected, no action takes place.  The Ctrl-Break is ignored.
*)

PROCEDURE InstallBreak (BreakProc: PROC );
(*
   - Install a break handler

     in:    BreakProc    break procedure to be called upon Crtl-Break

            A program can install its own break handler.  Module 'Break' maintains a
            stack of break procedures.  The break procedure on top of the stack (i.e.
            the one which was installed most recently) will be called upon the
            occurence of a ctrl-break.  The default break handler which is installed
            initially terminates the program with a call to
            'System.Terminate(stopped)'.

            Up to four user defined break procedure may be installed at the same time.
*)
```

```
PROCEDURE UnInstallBreak;
(*
   - Uninstall the current break handler

     Removes the break procedure which is currently on top of the stack.  So the last
     installed break procedure will be deactivated, and the one installed previously
     becomes active again.
*)

END Break.
```

Calendar

```
DEFINITION MODULE Calendar;

  (* This module defines a Date type and operations on dates of
     the Gregorian Calendar, introduced in 1582
  *)

  FROM DurationOps IMPORT
    Duration, Unit, UnitSet;

  FROM TimeDate IMPORT
    Time;

  TYPE Date =
         RECORD
           year      : CARDINAL;
           month     : [1 .. 12];
           day       : [1 .. 31];
           hour      : [0 .. 23];
           minute    : [0 .. 59];
           second    : [0 .. 59];
           thousandth: [0 .. 999];
         END; (* Date *)

  PROCEDURE GetMachineDate (VAR date: Date);
    (* Gets the machine date *)

  PROCEDURE SetMachineDate (date : Date);
    (* Sets the machine date *)

  PROCEDURE TimeToDate (time     : Time;
                        VAR date : Date);
    (* Type conversion from Time (in TimeDate) to Date (in Calendar) *)

  PROCEDURE DateToTime (date     : Date;
                        VAR time : Time);
    (* Type conversion from Date (in Calendar) to Time (in TimeDate) *)

  PROCEDURE IsValid (date : Date): BOOLEAN;
    (* Returns TRUE if date is valid, according to the Gregorian calendar *)

  PROCEDURE DaysIn (month : CARDINAL;
                    year  : CARDINAL): CARDINAL;
    (* Returns the number of days in the month of the year, according to
       the Gregorian calendar, 0 if month is out of range. *)

  PROCEDURE LeapYear (year : CARDINAL): BOOLEAN;
    (* Returns TRUE if year is a leap year, according to the Gregorian
       calendar (year number divisible by 400 or by 4 and not by 100) *)

  PROCEDURE SameDate (date1, date2 : Date;
                      precision    : Unit) : BOOLEAN;
    (* Returns TRUE if date1 and date2 are the same date, within precision *)
  PROCEDURE Later (date1, date2 : Date;
                   precision    : Unit) : BOOLEAN;
    (* Returns TRUE if date1 comes after date1, within precision *)

  PROCEDURE LaterOrSameDate (date1, date2 : Date;
                             precision    : Unit) : BOOLEAN;
    (* Returns TRUE if date2 is after date1 or if date1 and date2 are the same
       date, within precision *)


  (* The following operations give good results only with dates following
     October 15, 1582, when the Gregorian Calendar was first used.

     Accuracy to the second over long periods cannot be achieved, due to fluctuations
     in the Earth rotation that often cause annual corrections of one second.
  *)

  PROCEDURE AddToDate (date           : Date;
                       duration       : Duration;
                       VAR resultDate : Date);
    (* Add a duration to a date, gives a new date *)

  PROCEDURE SubToDate (date           : Date;
                       duration       : Duration;
                       VAR resultDate : Date);
    (* Subtract a duration from a date, gives a new date *)

  PROCEDURE DeltaDate (date1, date2 : Date;
                       unitFormat   : UnitSet;
                       VAR duration : Duration);
    (* Absolute value of the difference between two dates, given a duration
       with units in unitFormat (see module Duration) *)

END Calendar.
```

CardinalIO

```
DEFINITION MODULE CardinalIO;
(*
   Terminal input/output of CARDINALs in decimal and hex

   Derived from the Lilith Modula-2 system developed by the group of Prof. N. Wirth
   at ETH Zurich, Switzerland.
*)

EXPORT QUALIFIED
   ReadCardinal, WriteCardinal, ReadHex, WriteHex;


PROCEDURE ReadCardinal (VAR c: CARDINAL);
(*
   - Read an unsigned decimal number from the terminal.
     out:    c       the value that was read.

     The read terminates only on ESC, EOL, or blank, and the terminator
     must be re-read, for example with Terminal.Read.

     If the read encounters a non-digit, or a digit which would cause the number to
     exceed the maximum CARDINAL value, the bell is sounded and that character is
     ignored.  No more than one leading '0' is allowed.
*)

PROCEDURE WriteCardinal (c: CARDINAL; w: CARDINAL);
(*
   - Write a CARDINAL in decimal format to the terminal.
     in:     c       value to write,
             w       minimum field width.

     The value of c is written, even if it takes more than w digits.  If it takes
     fewer digits, leading blanks are output to make the field w characters wide.
*)

PROCEDURE ReadHex (VAR c: CARDINAL);
(*
   - Read a CARDINAL in hexadecimal format from the terminal.
     [see ReadCardinal above]
*)

PROCEDURE WriteHex (c: CARDINAL; digits: CARDINAL);
(*
   - Write a CARDINAL in hexadecimal format to the terminal.
     [see WriteCardinal above]
*)

END CardinalIO.
```

Chronometer

```
DEFINITION MODULE Chronometer;

 (* Management and use of 'Chrono' objects, which permits to measure times
    with an estimated accuracy of 0.02 second.
    All the operations on these chronos are similar to those on a real chronometer.
 *)

  FROM DurationOps IMPORT
    Duration,    (* The measured time will be of this type *)
    UnitSet;     (* The units to represent the time.       *)

  TYPE
    Chrono;

  PROCEDURE NewChrono (VAR chrono : Chrono);
    (* Creates a new variable of type Chrono ('Takes a chrono'), and resets it.
       A call to NewChrono is mandatory before any other operation, otherwise
       the program will be HALTed at any call of such an operation.
    *)

  PROCEDURE DisposeChrono (VAR chrono : Chrono);
    (* Destroys variable of type Chrono ('Drops the chrono')  It is illegal to call
       any operation with chrono as parameter other than NewChrono
       after a call to DisposeChrono.
    *)

  PROCEDURE StartChrono (chrono : Chrono);
    (* Starts the chrono.
       The chrono begins to measure elapsing time.
    *)

  PROCEDURE ReadChrono (chrono          : Chrono;
                        format          : UnitSet;
                        VAR elapsedTime : Duration);
    (* Reads the chrono, without stopping it.
       If format is empty then elapsedTime will be in seconds.
       A chrono can be read several times, elapsedTime holds the time elapsed since
       the last StartChrono of this chrono.
       Accuracy : 0.02 second
    *)

  PROCEDURE StopChrono (chrono : Chrono);
    (* Stops the chrono.
       The time elapsing after a call to StopChrono is not taken in account.
    *)

  PROCEDURE ResetChrono (chrono : Chrono);
    (* Stops and Resets the chrono.
       After a call to Reset the chrono is prepared to measure times from zero.
       Reset is automatically called by NewChrono.
    *)

END Chronometer.
```

Conversions

```
DEFINITION MODULE Conversions;
(*
   Convert from INTEGER and CARDINAL to string

   Derived from the Lilith Modula-2 system developed by the group of Prof. N. Wirth
   at ETH Zurich, Switzerland.
*)

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


PROCEDURE ConvertOctal(num, len : CARDINAL;
                       VAR str : ARRAY OF CHAR);
(*
   - Convert number to right-justified octal representation

     in:     num     value to be represented,
             len     minimum width of representation,
     out:    str     result string.

     If the representation of 'num' uses fewer than 'len' digits, blanks are added
     on the left.  If the representation will not fit in 'str', it is truncated
     on the right.
*)

PROCEDURE ConvertHex(num, len: CARDINAL;
                     VAR str: ARRAY OF CHAR);
(*
   - Convert number to right-justified hexadecimal representation.
     [see ConvertOctal]
*)

PROCEDURE ConvertCardinal(num, len : CARDINAL;
                          VAR str : ARRAY OF CHAR);
(*
   - Convert a CARDINAL to right-justified decimal representation.
     [see ConvertOctal]
*)

PROCEDURE ConvertInteger(num : INTEGER;
                         len : CARDINAL;
                     VAR str : ARRAY OF CHAR);
(*
   - Convert an INTEGER to right-justified decimal representation.
     [see ConvertOctal]

     Note that a leading '-' is generated if num < 0, but never a '+'.
*)
```

```
PROCEDURE ConvertLongInt(num : LONGINT;
                         len : CARDINAL;
                     VAR str : ARRAY OF CHAR);
(*
   - Convert a LONGINT to right-justified decimal representation.
     [see ConvertOctal]

     Note that a leading '-' is generated if num < 0, but never a '+'.
*)

END Conversions.
```

DateFormat

```
DEFINITION MODULE DateFormat;

(*
   Conversion between Date (from Calendar) and string types.

   An internal format, called current format holds the template of a string,
   i.e. the way in which a date is represented.  Routines are provided to
   change this format, as a whole or field by field.
*)

  FROM Calendar IMPORT
    Date;

  TYPE
    Format;

    Order  = (DateOnly,          (* Select Date and/or Time, and the     *)
              DateAndTime,       (* order in which they are represented. *)
              TimeOnly,
              TimeAndDate);

    DayFormat = (European,       (* day month year *)
                 US,             (* month day year *)
                 ISO);           (* year month day *)

    YearFormat = (Short,         (* 87   *)
                  Long);         (* 1987 *)

    MonthFormat = (InDigits,     (* 03                *)
                   InLetters);   (* March, Mars, ... *)

    MonthName = ARRAY [0 .. 15] OF CHAR;

    MonthList = ARRAY [1 .. 12] OF MonthName; (* Holds the months names, can *)
                                              (* be changed by user.         *)

    HourFormat = (PMSec,            (*  1:17:05 pm *)
                  PMNoSec,          (*  1:17 pm    *)
                  H24Sec,           (* 13:17:05    *)
                  H24NoSec);        (* 13:17       *)

    SeparatorList = ARRAY [0 .. 5] OF CHAR;   (* Holds the separators of the *)
                                              (* different date/time compo - *)
                                              (* components, can be changed  *)
                                              (* by the user.                *)

  PROCEDURE DefaultFormat (): Format;
    (* Returns default date format :
       dd-mmm-yyyy hh:mm:ss  i.e. 13-Jun-1987 17:45:30 *)

  PROCEDURE CurrentFormat (): Format;
    (* Returns current date format *)

  PROCEDURE SetFormat (format : Format);
    (* Sets the current format to format *)
  PROCEDURE SetOrder (order : Order);
    (* Sets the current format's order to order.
       (default: DateAndTime) *)

  PROCEDURE SetDayFormat (dayformat : DayFormat);
    (* Sets the current format's day format to dayFormat
       (default: European *)

  PROCEDURE SetYearFormat (yearFormat : YearFormat);
    (* Sets the current format's year format to yearFormat
       (default: Long) *)

  PROCEDURE SetMonthFormat (monthFormat : MonthFormat);
    (* Sets the current format's month format to monthFormat
       (default: InLetters) *)

  PROCEDURE SetMonthList (monthList : MonthList);
    (* Sets the current format's month list to monthList
       (default: Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec) *)

  PROCEDURE SetHourFormat (hourFormat : HourFormat);
    (* Sets the current format's hour format to hourFormat
       (default: H24Sec) *)

  PROCEDURE SetSeparator (separator : SeparatorList);
    (* Sets the current format's list to separator
       (default: "-- ::") *)

  PROCEDURE DateToString (date      : Date;
                          VAR image : ARRAY OF CHAR;
                          VAR done  : BOOLEAN);
    (* Converts a Date in a string of current format *)

  PROCEDURE StringToDate (image        : ARRAY OF CHAR;
                          VAR date     : Date;
                          VAR done     : BOOLEAN;
                          VAR errorPos : CARDINAL);
    (* Converts a string in a date.  The syntax of this string should be the one
      defined by the current format, otherwise done is set to FALSE and errorPos to
      the index of the first unexpected character of the string.
    *)

END DateFormat.
```

DebugPMD

```
DEFINITION MODULE DebugPMD;

END DebugPMD.
```

DebugTrace

```
DEFINITION MODULE DebugTrace;
(*
   (c) COPYRIGHT 1986,1987  LOGITECH SA, CH-1111 Romanel/Morges, Switzerland.

   Abstract : text
   Created  : 19-MAR-87  Reuteler

   Modified : dd-mmm-yy  Author Reason

*)

END DebugTrace.
```

Decimals

```
DEFINITION MODULE Decimals;
(*
   Decimal Arithmetic
*)

EXPORT QUALIFIED
   DECIMAL,  DecDigits, DecPoint, DecSep,   DecCur,    DecStatus,
   DecState, DecValid,  StrToDec, DecToStr, NegDec,    CompareDec,
   AddDec,   SubDec,    MulDec,   DivDec,   Remainder, DecRepr;

CONST
   DecDigits =  18;
   DecRepr   =  10;
   DecCur    = '$';
   DecPoint  = '.';
   DecSep    = ',';

TYPE
   DECIMAL  = ARRAY [0..DecRepr-1] OF CHAR;
     (*
        WARNING : Representation is implementation dependent!
     *)

   DecState = (NegOvfl,
               Minus,
               Zero,
               Plus,
               PosOvfl,
               Invalid
              );

VAR
   DecValid: BOOLEAN;
   (* set after every operation *)

   Remainder: CHAR;
   (* remainder digit - set after DivDec *)

PROCEDURE StrToDec (String: ARRAY OF CHAR;
                    Picture: ARRAY OF CHAR;
                    VAR Dec: DECIMAL);
(*
   Converts a DECIMAL number from an external format to an internal format;  after
   checking and matching between the picture and the input string.   The result is
   placed in variable Dec.
*)

PROCEDURE DecToStr  (Dec: DECIMAL;
                     Picture: ARRAY OF CHAR;
                     VAR RsltStr: ARRAY OF CHAR);
(*
   Converts a DECIMAL number from an internal format to an external format;  after
   checking and matching between the picture and the DECIMAL number.   The result is
   placed in variable RsltStr.
*)
```

```
PROCEDURE DecStatus (Dec: DECIMAL): DecState;
(*
   Detects the state of the number represented as DECIMAL
   and returns one of the following states :

   - Negative overflow      --> NegOvfl
   - Negative               --> Minus
   - Null                   --> Zero
   - Positive               --> Plus
   - Positive overflow      --> PosOvfl
   - Invalid representation --> Invalid
*)

PROCEDURE CompareDec (Dec0,Dec1: DECIMAL): INTEGER;
(*
   Compares two DECIMAL numbers and returns an integer value indicating the
   comparison result:

   -1 if Dec0 is less than Dec1
    0 if Dec0 equals Dec1
    1 if Dec0 is greater than Dec1
*)

PROCEDURE AddDec (Dec0,Dec1: DECIMAL; VAR Sum: DECIMAL);
(*
   Adds two DECIMAL numbers (Dec0 and Dec1) together and places the result in the
   variable Sum.
*)

PROCEDURE SubDec (Dec0,Dec1: DECIMAL; VAR Sub: DECIMAL);
(*
   Subtracts Dec1 from Dec0 and places the result in Sub.
*)

PROCEDURE MulDec (Dec0,Dec1: DECIMAL; VAR Prod: DECIMAL);
(*
   Multiplies two DECIMAL numbers and places the result in the variable Prod.
*)

PROCEDURE DivDec (Dec0,Dec1: DECIMAL; VAR Quot: DECIMAL);
(*
   Dec0 is divided by Dec1.  The quotient is placed in the variable Quot and the
   remainder is placed in the global variable Remainder.
*)

PROCEDURE NegDec (Dec: DECIMAL; VAR NDec: DECIMAL);
(*
   The negative DECIMAL value of Dec is placed in the variable NDec.
*)

END Decimals.
```

Delay

```
DEFINITION MODULE Delay;

EXPORT QUALIFIED
  Delay;

PROCEDURE Delay(milliSec: INTEGER);
(*
  Interrupts the program execution for approximatly 'milliSec' milliseconds.
*)

END Delay.
```

Devices

```
DEFINITION MODULE Devices;
(*
   Additional facilities for device and interrupt handling

   The MODULA-2/86 run-time support maintains a device mask that indicates from which
   devices interrupts are enabled.  The bits of the device mask have the same meaning
   as the bits in the mask register of the interrupt controller.

   Module 'Devices' provides access to the device mask.  It allows a program to
   inquire and change the status of a device (interrupts enabled or disabled).  The
   device numbers used by module 'Devices' and by the run-time support are equal to
   the number of the bit in the device mask, that indicates whether interrupts from
   this device are enabled or disabled.

   When a program is running at no priority, the mask register of the interrupt
   controller is identical to this device mask.  When a program is running at some
   priority, then the mask register of the interrupt controller is set to the logical
   OR of the device mask and the corresponding priority mask.  When the priority or
   the device mask changes, the MODULA-2/86 run-time support sets the mask register
   of the interrupt controller accordingly.  At any point in time, all the interrupts
   masked out, either in the device mask or in the current priority mask, are
   disabled.  The priority mask for 'no priority' does not mask out any interrupt,
   i.e. its value is all zeros.

   When writing interrupt handlers in MODULA-2/86, it is strongly recommended to use
   only the procedures provided by module 'Devices', and not to access directly the
   mask register of the interrupt controller.

   The following should be performed in order to install an interrupt handler: First
   save the old interrupt vector, then set up the interrupt handler (IOTRANSFER), and
   if necessary, save the current device status (interrupts enabled or disabled) and
   enable interrupts from the device.

   Before the program terminates, or in order to remove an interrupt handler, the
   following sequence of procedure calls should be performed: If necessary, restore
   the old device status or disable interrupts from the device, and then restore the
   old interrupt vector.

   At the end of a program the MODULA-2/86 run-time support resets the mask register
   of the interrupt controller to its initial value.

   In general, a call to IOTRANSFER in Modula-2 associates a process with only the
   next occurence of the specified interrupt.  The procedure 'InstallHandler'
   provided by module 'Devices' allows to install an interrupt handler permanently.
   It associates a process, the interrupt handler, permanently with a certain
   interrupt.

   While it is not required to install an interrupt handler in this way, it may be
   useful for handling time critical interrupts.  Installing an interrupt handler
   permanently improves the performance of IOTRANSFER and of the implicit coroutine
   transfer that takes place when the interrupt occurs by about 20 percent.

   'InstallHandler' must only be called after the process has been created (by means
   of NEWPROCESS) and before the process has called IOTRANSFER.  For instance, it may
   be called right at the beginning of the code of the process.
*)
```

```
FROM SYSTEM IMPORT ADDRESS, PROCESS;

EXPORT QUALIFIED
   GetDeviceStatus, SetDeviceStatus,
   SaveInterruptVector, RestoreInterruptVector,
   InstallHandler, UninstallHandler;

PROCEDURE GetDeviceStatus(deviceNr: CARDINAL;
                          VAR enabled: BOOLEAN);
(*
   - Return the status of a device in the device mask

     in:   deviceNr  number of the device to be checked bitnumber (0..7)
                     of bit for device in interrupt controller 8259 mask

     out:  enabled   TRUE if interrupts from the device are enabled, FALSE otherwise
*)

PROCEDURE SetDeviceStatus(deviceNr: CARDINAL;
                          enable: BOOLEAN);
(*
   - Set the status of a device in the device mask

     in:   deviceNr  number of the device to enable or disable bitnumber (0..7) of
                     bit for device in interrupt controller 8259 mask

           enable    if TRUE, enable interrupts from the device,
                     otherwise disable them

     The mask register of the interrupt controller will be updated according to the
     current priority and the new device mask.
*)

PROCEDURE SaveInterruptVector (vectorNr   : CARDINAL;
                               VAR vector : ADDRESS);
(*
   - Save the current value of an interrupt vector

   in:   vectorNr   interrupt vector number
   out:  vector     value of current interrupt vector
*)

PROCEDURE RestoreInterruptVector (vectorNr : CARDINAL;
                                  vector   : ADDRESS);
(*
   - Restore the value of an interrupt vector

     in:   vectorNr   interrupt vector number
           vector     value to restore (previously saved with 'SaveInterruptVector')
*)
```

```
PROCEDURE InstallHandler (process : PROCESS;
                          vectorNr: CARDINAL);
(*
   - Install an interrupt handler permanently

     in:   process    process associated with the interrupt handler
           vectorNr   interrupt vector number

   The process is associated permanently to the given interrupt vector number.  This
   improves the performance of IOTRANSFER and of the implicit coroutine transfer that
   takes place when the interrupt occurs.  A process may be associated to at most one
   interrupt, and at most one process may be associated to the same interrupt.

   'InstallHandler' must only be called after the process has been created (by means
   of NEWPROCESS) and before the process has called IOTRANSFER.  For instance, it may
   be called right at the beginning of the code of the process.  Except for the call
   to 'InstallHandler', the code of a permanently installed interrupt handler is
   identical to the code of a regular interrupt handler.
*)

PROCEDURE UninstallHandler(process: PROCESS);
(*
   - Uninstall an interrupt handler which has been installed permanently

     in:   process    process associated with the interrupt handler

     In general, there is no need to call this procedure.  The MODULA-2/86 run-time
     support automatically uninstalls interrupt handlers upon termination of a
     (sub-)program.
*)

END Devices.
```

Directories

```
DEFINITION MODULE Directories;
(*
   Additional directory operations
*)

EXPORT QUALIFIED
   DirQueryProc, DirResult, DirQuery,
   Delete, Rename;

TYPE
   DirQueryProc = PROCEDURE(ARRAY OF CHAR, VAR BOOLEAN);

   DirResult = (OK,
                ExistingFile, (* rename to existing name *)
                NoFile,       (* file not found *)
                OtherError);

PROCEDURE DirQuery(    wildFileName : ARRAY OF CHAR;
                       DirProc      : DirQueryProc;
                   VAR result       : DirResult);
(*
   - Apply the a procedure to all matching files

     in:   wildFileName  file name, wild-characters are allowed
           DirProc       procedure to be called for each file matching 'wildFileName'

     out:  result        result of directory operation

     'DirQuery' executes 'DirProc' on each file which satisfies the specification of
     'wildFileName' where wild-characters are allowed.  If no more files are found,
     or as soon as 'DirProc' returns FALSE, the execution is stopped.

     If an incorrect filename is passed, this may return a 'result <> OK', and
     'DirProc' will not be called.

     Possible results are OK, NoFile, or OtherError.
*)

PROCEDURE Delete (FileName     : ARRAY OF CHAR;
                  VAR result   : DirResult);

(*
   - Delete a file.

     in:   FileName   name of the file to delete

     out:  result     result of directory operation

     Possible results are OK, or NoFile.
*)
```

```
PROCEDURE Rename(    FromName : ARRAY OF CHAR;
                     ToName   : ARRAY OF CHAR;
                 VAR result   : DirResult);
(*
   - Rename a file.

     in:   FromName   name of the file to rename
           ToName     new name of the file

     out:  result     result of directory operation

     Possible results are OK, NoFile, ExistingFile, or OtherError.
*)

END Directories.
```

DiskDirectory

```
DEFINITION MODULE DiskDirectory;
(*
   Interface to directory functions of the underlying OS

   Derived from the Lilith Modula-2 system developed by thegroup of Prof. N. Wirth
   at ETH Zurich, Switzerland.
*)

EXPORT QUALIFIED
    CurrentDrive, SelectDrive,
    CurrentDirectory, ChangeDirectory,
    MakeDir, RemoveDir,
    ResetDiskSys, ResetDrive;

PROCEDURE CurrentDrive (VAR drive: CHAR);
(*
   - Returns the current default drive.

     out:    drive   name of the default drive, given in character format (e.g. 'A').
*)

PROCEDURE SelectDrive (drive: CHAR; VAR done: BOOLEAN);
(*
   - Set default drive.

     in:     drive   name of drive to make default, specified in
                     character format (e.g. 'A').

     out:    done    TRUE if operation was successful.

     The default drive will be used by all routines referring to DK: .
*)

PROCEDURE CurrentDirectory (drive   : CHAR;
                            VAR dir : ARRAY OF CHAR);
(*
   - Gets the current directory for the specified drive.

     in:     drive   name of the drive, specified in character format (e.g. 'A');
                     blank or 0C denotes the current drive.

     out:    dir     current directory for that drive.

     Because CP/M-86 does not support named directories, dir[0] will always be set
     to nul (0C) under CP/M-86.
*)
```

```
PROCEDURE ChangeDirectory      (dir: ARRAY OF CHAR;
                           VAR done: BOOLEAN);
(*
   - Set the current directory

     in:     dir     drive and directory path name.

     out:    done    TRUE if successful; FALSE if the directory does not exist.

     Because CP/M-86 does not support named directories, this function has no effect
     and 'done' returns always FALSE under CP/M-86.
*)

PROCEDURE MakeDir (dir      : ARRAY OF CHAR;
                   VAR done : BOOLEAN);
(*
   - Create a sub-directory

     in:     dir     drive, optional pathname and name of sub-directory to create.

     out:    done    TRUE if successful; FALSE if path or drive does not exist.

     Because CP/M-86 does not support named directories, this function has no effect
     and 'done' returns always FALSE under CP/M-86.
*)

PROCEDURE RemoveDir      (dir : ARRAY OF CHAR;
                     VAR done : BOOLEAN);
(*
   - Remove a directory

     in:     dir     drive and name of the sub-directory to remove.

     out:    done:   TRUE if successful; FALSE if directory does not exist.

     The specified directory must be empty, otherwise 'done' returns FALSE and the
     directory is not removed.

     Because CP/M-86 does not support named directories, this function has no effect
     and 'done' returns always FALSE under CP/M-86.
*)

PROCEDURE ResetDiskSys;
(*
   - MS-DOS or CP/M-86 disk reset
*)

PROCEDURE ResetDrive (d: CHAR): CARDINAL;
(*
   - CP/M-86 reset drive.

     in:     drive   name of drive to make default, specified in
                     character format (e.g. 'A').

     out:            returns always zero under CP/M-86

     Under DOS this function has no effect and returns always the value 255.
*)

END DiskDirectory.
```

DiskFiles

```
DEFINITION MODULE DiskFiles;
(*
   Interface to disk file functions of the underlying OS.
   [Private module of the MODULA-2/86 system.]

   The default drive 'DK:', and drives 'A:' through 'P:' are supported
   under DOS or CP/M-86.  This driver provides buffering.  The maximum number of open
   files is 12.

   Derived from the Lilith Modula-2 system developed by thegroup of Prof. N. Wirth
   at ETH Zurich, Switzerland.
*)

FROM FileSystem IMPORT File;

EXPORT QUALIFIED
  InitDiskSystem,
  DiskFileProc, DiskDirProc;


PROCEDURE InitDiskSystem;
(*
   - Initialize mediums for further disk file operations

     This procedure has to be imported by FileSystem.  This has the side-effect, that
     this module is referenced and will therefore be linked to the user program.
*)


PROCEDURE DiskFileProc (VAR f: File);
(*
   - low-level interface for disk operations within a file

     This procedure is passed as a parameter to the procedure
     CreateMedium in FileSystem.
*)


PROCEDURE DiskDirProc (VAR f     : File;
                           name  : ARRAY OF CHAR);
(*
   - low-level interface for disk operations within a directory

     This procedure is passed as a parameter to the procedure
     CreateMedium in FileSystem.
*)

END DiskFiles.
```

Display

```
DEFINITION MODULE Display;
(*
   Low-level Console Output
   [Private module of the MODULA-2/86 system]

   Derived from the Lilith Modula-2 system developed by thegroup of Prof. N. Wirth
   at ETH Zurich, Switzerland.
*)

EXPORT QUALIFIED Write;

PROCEDURE Write (ch: CHAR);
(*
   - Display a character on the console.

     in:     ch      character to be displayed.

     The following codes are interpreted:

         ASCII.EOL  (36C) = go to beginning of next line
         ASCII.ff   (14C) = clear screen and set cursor home
         ASCII.del (177C) = erase the last character on the left
         ASCII.bs   (10C) = move 1 character to the left
         ASCII.cr   (15C) = go to beginning of current line
         ASCII.lf   (12C) = move 1 line down, same column

     Write uses direct console I/O.
*)

END Display.
```

DOS3

```
DEFINITION MODULE DOS3;
(*
   Additional DOS 3.0 functions
*)

  FROM SYSTEM IMPORT
    BYTE, WORD, ADDRESS;

  EXPORT QUALIFIED
    GetExtendedError,
    CreateTemporaryFile,
    CreateNewFile,
    LockUnlockFileAccess,
    GetProgramSegmentPrefix;

  (* DOS 3.0 function 59H *)
  PROCEDURE GetExtendedError(version             : WORD;
                             (* BX *)
                             VAR extendedError   : WORD;
                             (* AX *)
                             VAR errorClass      : BYTE;
                             (* BH *)
                             VAR suggestedAction : BYTE;
                             (* BL *)
                             VAR locus           : BYTE);
                             (* CH *)

  (* DOS 3.0 function 5AH *)
  PROCEDURE CreateTemporaryFile(path            : ADDRESS;
                                (* DS:DX *)
                                attribute       : WORD;
                                (* CX    *)
                                VAR errorCode   : WORD;
                                (* AX,CF *)
                                VAR handle      : WORD;
                                (* AX,CF *)
                                VAR pathAndName : ADDRESS);
                                (* DS:BX *)


  (* DOS 3.0 function 5BH *)
  PROCEDURE CreateNewFile(pathAndName      : ADDRESS;
                          (* DS:BX *)
                          attribute        : WORD;
                          (* CX    *)
                          VAR errorCode    : WORD;
                          (* AX,CF *)
                          VAR handle       : WORD);
                          (* AX,CF *)
  (* DOS 3.0 function 5CH *)
  PROCEDURE LockUnlockFileAccess(lock           : BYTE;
                                 (* AL    *)
                                 handle         : WORD;
                                 (* BX    *)
                                 offsetHigh     : WORD;
                                 (* CX    *)
                                 offsetLow      : WORD;
                                 (* DX    *)
                                 lengthHigh     : WORD;
                                 (* SI    *)
                                 lengthLow      : WORD;
                                 (* DI    *)
                                 VAR errorCode  : WORD);
                                 (* AX,CF *)

  (* DOS 3.0 function 62H *)
  PROCEDURE GetProgramSegmentPrefix(VAR PSPsegment : WORD);
                                   (* BX *)

END DOS3.
```

DOS31

```
DEFINITION MODULE DOS31;
(*
   Additional DOS 3.1 functions
*)

  FROM SYSTEM IMPORT
    BYTE, WORD, ADDRESS;

  EXPORT QUALIFIED
    GetMachineName,
    SetPrinterSetup,
    GetPrinterSetup,
    GetRedirectionListEntry,
    RedirectDevice,
    CancelRedirection;

    (* DOS 3.1 function 5E00H *)
    PROCEDURE GetMachineName(computerName          : ADDRESS;
                             (* DS:DX *)
                             VAR nameNumberIndFlag : BYTE;
                             (* CH *)
                             VAR nameNumber        : BYTE;
                             (* CL *)
                             VAR errorCode         : WORD);
                             (* AX,CF *)

    (* DOS 3.1 function 5E02H *)
    PROCEDURE SetPrinterSetup(redirectionListIndex : WORD;
                              (* BX *)
                              setupStringLength    : WORD;
                              (* CX *)
                              setupBuffer          : ADDRESS;
                              (* DS:SI *)
                              VAR errorCode        : WORD);
                              (* AX,CF *)

    (* DOS 3.1 function 5E03H *)
    PROCEDURE GetPrinterSetup(redirectionListIndex  : WORD;
                              (* BX *)
                              setupBuffer           : ADDRESS;
                              (* ES:DI *)
                              VAR setupStringLength : WORD;
                              (* CX *)
                              VAR errorCode         : WORD);
                              (* AX,CF *)
    (* DOS 3.1 function 5F02H *)
    PROCEDURE GetRedirectionListEntry
                    (redirectionIndex     : WORD;
                     (* BX *)
                     localDeviceName      : ADDRESS;
                     (* DS:SI *)
                     networkName          : ADDRESS;
                     (* ES:DI *)
                     VAR deviceStatusFlag : BYTE;
                     (* BH *)
                     VAR deviceType       : BYTE;
                     (* BL *)
                     VAR storedParmValue  : WORD;
                     (* CX *)
                     VAR errorCode        : WORD);
                     (* AX,CF *)

    (* DOS 3.1 function 5F03H *)
    PROCEDURE RedirectDevice(deviceType           : BYTE;
                             (* BL *)
                             valueToSaveForCaller : WORD;
                             (* CX *)
                             deviceName           : ADDRESS;
                             (* DS:SI *)
                             networkPath          : ADDRESS;
                             (* ES:DI *)
                             VAR errorCode        : WORD);
                             (* AX,CF *)

    (* DOS 3.1 function 5F04H *)
    PROCEDURE CancelRedirection(deviceName        : ADDRESS;
                                (* DS:SI *)
                                VAR errorCode     : WORD);
                                (* AX,CF *)

END DOS31.
```

DosError

```
DEFINITION MODULE DosError;

  (* Get the DOS error message associated to an error code. *)

  PROCEDURE GetErrorMessage (errorCode       : CARDINAL;
                             VAR errorMessage : ARRAY OF CHAR);
    (* errorCode is an error number returned by DOS functions.
       errorMessage is at most 40 character long *)

END DosError.
```

DOSMemory

```
(* This is an interface to the DOS memory allocation ( DOSCALL 48H, 49H, 4AH )
 * The blocks are linked to the Modula-2 RunTime Support, thus they are known
 * by the system and dumped in case of error.
*)

DEFINITION MODULE DOSMemory;

FROM SYSTEM IMPORT ADDRESS;

EXPORT QUALIFIED DOSAlloc, DOSDeAlloc, DOSAvail, DOSSetSize, DOSGetMaxSize;


PROCEDURE DOSAlloc( VAR a: ADDRESS; paraSize: CARDINAL );
   (* Allocates a block of paraSize paragraphs :                       *)
   (*   a is the address of the block returned or NIL if the size      *)
   (*   is not available or an error occured                           *)

PROCEDURE DOSDeAlloc( VAR a: ADDRESS; paraSize: CARDINAL );
   (* DeAllocates a block previously allocated with DOSAlloc.  The     *)
   (* paraSize passed must be the size given for allocate or setsize   *)
   (*   a is set to the NIL value if DeAlloc succeds, not modified     *)
   (*   an error occured.                                              *)
   (* NOTE: the address passed MUST BE the address returned by        *)
   (*       DOSAlloc                                                   *)

PROCEDURE DOSAvail(): CARDINAL;
(* Function that returns the size ( in paragraphs ) of the largest    *)
(* space available.                                                   *)

PROCEDURE DOSSetSize( a: ADDRESS; paraSize: CARDINAL; VAR errorCode: CARDINAL );
(* Sets the size of the block given to the new size given in paraSize. *)
(* The returned errorCode is :                                         *)
(*      0 : No Error                                                   *)
(*      7 : memory control block destroyed                             *)
(*      8 : insufficient memory                                        *)
(*      9 : incorrect block address                                    *)
(* NOTE: the address passed MUST BE the address returned by DOSAlloc   *)

PROCEDURE DOSGetMaxSize( a: ADDRESS ): CARDINAL;
(* Gets the maximal paragraph size to which the block given as         *)
(* parameter can be extended                                           *)
(* NOTE: the address passed MUST BE the address returned by DOSAlloc   *)

END DOSMemory.
```

DurationOps

```
DEFINITION MODULE DurationOps;

(* This module defines a Duration type and the relevant units.

   It allows comparisons, addition and substraction on the Duration type,
   and a way to do conversion between units with ease.
*)

  TYPE Unit = (Millenium, Century, Year, Month,
               Day, Hour, Minute, Second,
               Tenth, Hundredth, Thousandth);

    (* Year  = mean solar time year: 365 days 5 hours 49 minutes 12 seconds
                                     31 556 952 seconds
       Month = Year / 12           :  2 629 746 seconds
    *)

  TYPE Duration = ARRAY Unit OF REAL;
    (* Each cell of this array will hold the real amount of the relevant
       unit.
    *)

  TYPE UnitSet = SET OF Unit;

  CONST
    FullUnitSet  = UnitSet {Millenium, Century, Year, Month,
                            Day, Hour, Minute, Second,
                            Tenth, Hundredth, Thousandth};

    EmptyUnitSet = UnitSet {};

  PROCEDURE Clear (VAR duration  : Duration);
    (* Set duration to zero *)

  PROCEDURE Format (VAR duration : Duration;
                    format       : UnitSet);
    (* Formatting of duration in format.
       Allows conversions between duration units.
       Unit cells of duration not in format are set to 0.0.
         Those in format are set to the greatest possible 'integer' value, except
         for the smallest unit which contains the remainder which may not be integer.
       If format is empty, duration is reformatted with the same units.
    *)

  PROCEDURE FormatOf (duration : Duration): UnitSet;
    (* Returns the format of duration, i.e. the set of the non zero  unit cells. *)

  PROCEDURE Sum (left, right : Duration;
                 format      : UnitSet;
                 VAR result  : Duration);
    (* Addition of left and right, result being formatted with format.  If format is
       empty then result is formatted with the union of left and right formats
    *)
  PROCEDURE Diff (left, right : Duration;
                  format      : UnitSet;
                  VAR result  : Duration);
    (* Substraction of left and right, result being formatted with format.  If format
       is empty then result is formatted with the union of left and right formats
    *)

  PROCEDURE Equal (left, right : Duration;
                   accuracy    : Unit) : BOOLEAN;
    (* Returns TRUE if left and right are equal within accuracy  *)

  PROCEDURE Greater (left, right : Duration;
                     accuracy    : Unit) : BOOLEAN;
    (* Returns TRUE if left is greater than right within accuracy  *)

  PROCEDURE GreaterOrEqual (left, right : Duration;
                            accuracy    : Unit) : BOOLEAN;
    (* Returns TRUE if left is greater or equal than right within accuracy  *)

END DurationOps.
```

DynMem

```
DEFINITION MODULE DynMem;

FROM SYSTEM  IMPORT ADDRESS;

EXPORT QUALIFIED  InstallDynMem, Alloc, DeAlloc, Avail;

(* for all procedures below, the block address must be paragraph aligned   *)
(* with offset 0                                                           *)

PROCEDURE InstallDynMem( block : ADDRESS;
                         size  : CARDINAL );
(* size is the size in bytes usable by DynMem and it must be < MaxInt      *)

PROCEDURE Alloc( block    : ADDRESS;
                 VAR adr  : ADDRESS;
                 size     : CARDINAL );
(* adr will be the allocated block address or NIL if no space available    *)
(* size is in bytes                                                        *)

PROCEDURE DeAlloc (  block : ADDRESS;
                   VAR adr : ADDRESS;
                   size    : CARDINAL ): BOOLEAN;
(* adr return value will be NIL                                            *)

PROCEDURE Avail  ( block : ADDRESS;
                   size : CARDINAL ): BOOLEAN;
(* returns TRUE if size is available in the block                          *)

END DynMem.
```

ErrorCode

```
DEFINITION MODULE ErrorCode;
(*
   handle return code to operating system
*)

  EXPORT QUALIFIED
    SetErrorCode, GetErrorCode, ExitToOS;

  PROCEDURE SetErrorCode(value: CARDINAL);
  (*
     Sets the error return code that will be used on normal termination;
     but it doesn't terminate the program immediately.
  *)

  PROCEDURE GetErrorCode(VAR value: CARDINAL);
  (*
     Allows to inspect the set return code
  *)

  PROCEDURE ExitToOS;
  (*
     Terminate current program and return to operating system.  Set the error code
     corresponding to value defined by a previous call to SetErrorCode.
     implementation restriction: if the program is using overlays, only the current
     overlay will be terminated.
  *)

END ErrorCode.
```

Exec

```
DEFINITION MODULE Exec;
  FROM SYSTEM IMPORT ADDRESS;

  EXPORT QUALIFIED
    DosShell, DosCommand, Run, Execute;

  PROCEDURE DosShell(VAR done: BOOLEAN);
  (* call "COMMAND.COM"                                             *)
  (* remain in DOS command shell, until user types EXIT             *)
  (* finds COMMAND.COM through environment variable COMSPEC=        *)

  PROCEDURE DosCommand (command, parameters  : ARRAY OF CHAR;
                                   VAR done : BOOLEAN);
  (* call COMMAND.COM/c command parameters                          *)
  (* execute just one DOS command and return                        *)
  (* finds COMMAND.COM through environment variable COMSPEC=        *)
  (* here, the DOS shell will perform a search strategy,            *)
  (* using the PATH= environment variable                           *)
  (* This call can be used to perform built in commands of          *)
  (* DOS (e.g. dir, ren, copy ...)                                  *)

  PROCEDURE Run (programFileName, parameters  : ARRAY OF CHAR;
                                   VAR done : BOOLEAN);
  (* call program with parameters                                   *)
  (* the complete filename with drive,                              *)
  (* path and extension has to be passed.                           *)
  (* no search strategy will be performed                           *)

  PROCEDURE Execute (programFileNameAdr: ADDRESS;
                         (* pointer to program filename *)
                        environment : CARDINAL;
                          (* paragraph address of environment *)
                          (* 0 for current environment *)
                     commandLineAdr : ADDRESS;
                          (* pointer to command line parameters *)
                          (* first byte is number of characters in command line *)
                          (* next characters contain parameters              *)
                   FCB1Adr, FCB2Adr : ADDRESS;
                          (* pointer to default file control blocks *)
                      VAR errorCode : CARDINAL
                          (* DOS error code *)
                  );
  (* call program with given parameter block information *)
  (* no search strategy will be performed               *)

END Exec.
```

FileMessage

```
DEFINITION MODULE FileMessage;
(*
   Write file status/response to the terminal
*)

FROM FileSystem IMPORT Response;

EXPORT QUALIFIED WriteResponse;

PROCEDURE WriteResponse (r: Response);
(*
   - Write a short description of a FileSystem response on the terminal.

     in:     r       the response from some FileSystem operation.

     The actual argument for 'r' is typically the field 'res' of a variable of
     type 'File'.  The printed message is up to 32 characters long.
*)

END FileMessage.
```

FileNames

```
DEFINITION MODULE FileNames;
(*
   Read a file specification from the terminal.

   Derived from the Lilith Modula-2 system developed by the group of Prof. N. Wirth
   at ETH Zurich, Switzerland.
*)

EXPORT QUALIFIED
  FNParts, FNPartSet, ReadFileName;

TYPE
  FNParts   = (FNDrive, FNPath, FNName, FNExt);
  FNPartSet = SET OF FNParts;

PROCEDURE ReadFileName (VAR resultFN   : ARRAY OF CHAR;
                        defaultFN      : ARRAY OF CHAR;
                        VAR ReadInName : FNPartSet);
(*
   - Read a file specification from terminal.

     in:     defaultFN       default file specification,
     out:    resultFN        the file specification read,
             ReadInName      which parts are in specification.

     Reads until a <cr>, blank, <can>, or <esc> is typed.  After a call to
     ReadFileName, Terminal.Read must be called to read the termination character.
     The format of the specification depends on the host operating system.
*)

END FileNames.
```

FileSystem

```
DEFINITION MODULE FileSystem;
(*
   File manipulation routines

   This implementation is based on the underlying operating system for file handling.
   It distinguishes between BINARY files and TEXT files.

   File structure:

      After any file operation the result should be checked for errors, by testing
      the field 'res' of the file variable (see type declarations for 'File'
      and 'Response').

      The BOOLEAN field 'eof' in a file variable (variable of type 'File)' allows to
      determine the end-of-file.  It is set to TRUE after the first unsuccessful
      attempt to read information from the file.  This first attempt to read beyond
      end-of-file does not set any error condition; the field 'res' of the file
      variable still  indicates 'done'. However, the character (or other data)
      returned is not valid.

   Binary files:

      A file is a sequence of bytes with no other structure implied.

      Under some operating systems (e.g. CP/M-86) the file may be organized in
      records (128 bytes each), and therefore, the length of a file will always be a
      multiple of this record size.

   Text files:

      A file is a sequence of characters.  The character code 32C (Ctrl-Z) indicates
      end-of-file).  All other character codes from 0C to 377C are legal.  When
      reading a text file, 'eof' becomes TRUE when encountering the character 32C, or
      at the pysical end of the file.  When closing a text file that has been
      modified, the character 32C is written on the file.

      When reading from a text file (by means of procedure 'ReadChar'), the character
      ASCII.EOL is returned for the sequence <CR, LF>, or for a single <CR> or <LF>.
      When writing to a text file (by means of procedure 'WriteChar'), the character
      ASCII.EOL is changed to the sequence <CR,LF>.
      An open file is in one of the states 'opened', 'reading', 'writing', or
      'modifying'.  These states have the following meaning:

      opened    = Content of file buffer is undefined and not associated with
                  a position in the file.
                  When starting to read or write from a file that is in state open,
                  the state is changed implicitly to reading or writing.
      reading   = No writing is allowed.
      writing   = No reading is allowed.  Writing always takes place at the end-of-
                  file position.
                  When writing on an existing file, which is (physically) longer than
                  the current write position, it is undefined, whether the file
                  is truncated upon a close.
      modifying = Reading and writing are allowed.  Writing an element inside of a
                  file means 'overwriting' the value of the element with a new value.
                  Upon a close, the file is not truncated.

      The state of the file is given by the field 'flags' of a file variable.  By
      means of the procedures SetRead, SetWrite, SetModify, and SetOpen, it is
      possible to change the state of an open file.

      To every file is associated a 'current position'.  This corresponds to the
      number of the current byte inside the file, starting with zero for the first
      byte.  The next reading or writing takes place at the current position.  This
      position is updated automatically after reading or writing.  It can also be
      inquired or set through the procedure GetPos or SetPos.

      After the opening of a file (by means of Lookup or Create) it is state 'opened'
      and positioned at the beginning (low = 0, high = 0).

   Conventions for filenames:

      For the procedures Lookup and Rename, a filename has to be given, including a
      medium name (drive name), a file name and an optional file type.  For the
      procedure Create, a medium name has to be given.  The medium name is up to
      three characters long (alphanumeric, starting with a letter).  It is separated
      from the file name by a colon (':').  If no medium name is given, the current
      default medium (drive) is assumed.  The default medium may also be denoted
      by 'DK:'.

      Depending on the operating system, the file name may include a path name,
      specifying the the directory where the file exists.  The length of the file
      (and path) name, and the characters legal for file names, depend on the
      operating system.

      By default, the mediums (i.e. disk drives) handled by module 'DiskFiles'
      are installed.

      Derived from the Lilith Modula-2 system developed by the group of
      Prof. N. Wirth at ETH Zurich, Switzerland.
*)
```

```
FROM SYSTEM IMPORT ADDRESS, WORD, BYTE;

EXPORT QUALIFIED
   File, Response, Command,
   Flag, FlagSet,

   (* basic file operations: *)
   Create,  Close,    Lookup,     Rename, Delete,
   SetRead, SetWrite, SetModify,  SetOpen,
   Doio,
   SetPos,  GetPos,   Length,

   (* stream-like I/O: *)
   Reset, Again,
   ReadWord,  ReadChar,  ReadByte,  ReadNBytes,
   WriteWord, WriteChar, WriteByte, WriteNBytes,

   (* medium handling: *)
   MediumType,
   FileProc,     DirectoryProc,
   CreateMedium, RemoveMedium,

   FileNameChar;

TYPE

   MediumHint = CARDINAL;
   (*- medium index used in DiskFiles *)

   MediumType = ARRAY [0..2] OF CHAR;
   (*- medium name (A, B...) *)

   Flag     = (er, ef, rd, wr, ag, txt);
   (*
      - status flag for file operations:

      er = error occured, ef = end-of-file reached,
      rd = in read mode,  wr = in write mode,
      ag = "Again" has been called after last read,
      txt = text-file (the last access to the file was a
      'WriteChar' or 'ReadChar').
   *)
```

```
FlagSet  = SET OF Flag;
(*- status flag set *)

Response = (done, notdone, notsupported, callerror,
            unknownmedium, unknownfile, paramerror,
            toomanyfiles, eom, userdeverror);
(*
   - result of a file operation

     done:
       FileSystem routine successfully terminated notsupported:
       for internal purposes only
     callerror:
       a) You tried to write to a file currently in state reading.  Use SetWrite
          to change a file's state from reading to writing.
       b) You tried to read from a file currently in state writing.  Use SetRead
          to change a file's state from writing to reading.
       c) You tried to read from or write to a file marked as invalid by the
          following operations:
                unsuccessful   Create or Lookup
                successful     Close or Delete
     unknownmedium:
       The medium, or drive, which you addressed does not exist or is not known to
       the MODULA-2/86 System (it has not been installed by means of the
       CreateMedium routine).
     unknownfile:
       The file you specified as the parameter for the Delete routine
       could not be found.
     paramerror:
       a) The syntax of the medium name, or drive name, which you specified
          is incorrect.
       b) When renaming a file, you must not change the medium name (drive name).
       c) You tried to position a file after its physical end.
     toomanyfiles:
       Only 12 files can be opened at the same time.
     eom:
       'end of medium' - The medium (disk) holding the file, to which you wanted
       to write is short of storage space.
     userdeverror:
       Not used in this implementation of the FileSystem.
     notdone:
       a) You tried to read from a file for which the BOOLEAN field eof of the
          corresponding file variable is true.
       b) You tried to open a non-existing file with Lookup
          (with parameter newFile = FALSE).
       c) Any other error, not covered by the above meanings of the
          values of the FileSystem Response Type.
*)

Command  = (create,  close,    lookup,    rename, delete,
            setread, setwrite, setmodify, setopen,
            doio,    setpos,   getpos,    length);
(*- commands passed to module 'DiskFiles' *)

BuffAdd  = POINTER TO ARRAY [0..0FFFEH] OF CHAR;
(*- file buffer pointer type *)
```

```
   File     = RECORD
                bufa          : BuffAdd;
                   (*- buffer address *)
                buflength     : CARDINAL;
                   (*- size of buffer in bytes.  In the current release it is always
                       a multiple of 128. *)
                validlength : CARDINAL;
                   (*- number of valid bytes in buffer *)
                bufind: CARDINAL;
                   (*- byte-index to the buffer of the current position *)
                flags         : FlagSet;
                   (*- status of the file *)
                eof           : BOOLEAN;
                   (*- TRUE if last access was past the end of the file *)
                res           : Response;
                   (*- result of last operation *)
                lastRead      : CARDINAL;
                   (*- the word or byte (char) last read *)
                mt            : MediumType;
                   (*- selects the driver that supports this file *)
                fHint         : CARDINAL;
                   (*- used internally by device driver *)
                mHint         : MediumHint;
                   (*- used internally by medium handler *)
                CASE com: Command OF
                  lookup: new: BOOLEAN;
                | setpos,
                  getpos,
                  length: highpos, lowpos: CARDINAL;
                END;
              END;
   (*- file structure used for bookkeeping by DiskFiles *)

PROCEDURE Create (VAR f       : File;
                  mediumName : ARRAY OF CHAR);
(*
   - create a temporary file

     in:     mediumName   name of medium to create file on, in character format

     out:    f            initialized file structure

     A temporary file is characterized by an empty name.  To make the file permanent,
     it has to  be renamed with a non-empty name before closing it.  For subsequent
     operations on this file, it is referenced by 'f'.
*)

PROCEDURE Close (VAR f: File);
(*
   - Close a file

     in:     f       structure referencing an open file

     out:    f       the field f.res will be set appropriately.

     Terminates the operations on file "f".  If "f" is a temporary file, it will be
     destroyed, whereas a file with a non-empty name remains on its medium and is
     accessible through "Lookup".  When closing a text-file after writing, the end-
     of-file code 32C is written on the file (MS-DOS and CP/M-86 convention).
*)
```

```
PROCEDURE Lookup (VAR f: File; fileName: ARRAY OF CHAR;
                  newFile: BOOLEAN);
(*
  - look for a file

     in:  filename    drive and name of file to search for
          newFile     TRUE if file should be created if not found

     out: f           initialized file structure; f.res will be set appropriately.

     Searches the medium specified in "filename" for a file that matches the name and
     type given in "filename".  If the file is not found and "newFile" is TRUE, a new
     (permanent) file with the given name and type is created. If it is not  found
     and "newFile" is FALSE, no action takes place and "notdone" is returned  in the
     result field of "f".
*)

PROCEDURE Rename (VAR f: File; newname: ARRAY OF CHAR);
(*
  - rename a file

     in:  f          structure referencing an open file
          newname    filename to rename to, with device:name.type specified

     out: f          file name in f will be changed and the field f.res
                     will be set appropriately.

     The medium, on which the files reside can not be changed with this command.  The
     medium name inside "newname" has to be the old one.
*)

PROCEDURE Delete (name: ARRAY OF CHAR; VAR f: File);
(*
  - delete a file

     in:     name    name of file to delete, with dev:name.type specified

     out:    f       the field f.res will be set appropriately.
*)

PROCEDURE ReadWord (VAR f: File; VAR w: WORD);
(*
  - Returns the word at the current position in f

     in:     f       structure referencing an open file

     out:    w       word read from file
             f       the result field f.res will be set appropriately.

     The file will be positioned at the next word when the read is done.
*)
```

```
PROCEDURE WriteWord (VAR f: File; w: WORD);
(*
   - Write one word to a file

     in:     f       structure referencing an open file
             w       word to write

     out:    f       the field f.res will be set appropriately.

     When overwriting, the file will be positioned at the next word
     when the write is done.
*)


PROCEDURE ReadChar (VAR f: File; VAR ch: CHAR);
(*
   - Read one character from a file

     in:     f       structure referencing an open file

     out:    ch      character read from file
             f       the field f.res will be set appropriately.

     ReadChar returns the character contained in the referenced file at
     the file's current position, with the following exceptions:

     (The symbolic constants are from the Standard Library module ASCII.DEF)

     Character Sequence           Character Returned
        in File:
     Symbolic      Octal          Symbolic     Octal
     ---------------------------------------------
     <cr, lf>      15C, 12C         <EOL>        36C
     <cr>          15C              <EOL>        36C
     <lf>          12C              <EOL>        36C
     <Ctrl-z>      32C              <nul>         0C

     <Ctrl-z>, i.e. 32C, indicates end-of-file.

     If ReadChar encounters the end of the file or tries to read beyond it, a nul
     character, or 0C, is returned.

     The file will be positioned at the next character when the read is done.
*)
```

```
PROCEDURE WriteChar (VAR f: File; ch: CHAR);
(*
   - Write one character to a file

     in:      f       structure referencing an open file
              ch      character to write

     out:     f       the field f.res will be set apporopriately.


     WriteChar writes the character to the referenced file at the file's current
     position, with the following exceptions:

     (The symbolic constants are from the Standard Library module ASCII.DEF)

     Character to write          Character Sequence
                                      in File:
     Symbolic     Octal          Symbolic     Octal
     ---------------------------------------------
     <EOL>         36C           <cr, lf>     15C, 12C
     <cr>          15C           <cr>         15C
     <lf>          12C           <lf>         12C
     <Ctrl-z>      32C           <Ctrl-z>     32C

     <Ctrl-z>, i.e. 32C, indicates end-of-file.

     When overwriting, the file will be positioned at the next character
     when the write is done.

*)

PROCEDURE ReadByte (VAR f: File; VAR b: BYTE);
(*
   - Read one byte from a file

     in:      f       structure referencing an open file

     out:     b       byte read from file
              f       the field f.res will be set appropriately.

     The file will be positioned at the next byte when the  read is completed.
*)

PROCEDURE WriteByte (VAR f: File; b: BYTE);
(*
   - Write one byte to a file

     in:      f       structure referencing an open file
              b       byte to write

     out:     f       the field f.res will be set appropriately.

     When overwriting, the file will be positioned at the next byte
     when the write is done.
*)
```

```
PROCEDURE ReadNBytes (VAR f          : File;
                      bufPtr         : ADDRESS;
                      requestedBytes : CARDINAL;
                      VAR read       : CARDINAL);
(*
   - Read a specified number of bytes from a file

     in:    f               structure referencing an open file
            bufPtr          pointer to buffer area to read bytes into
            requestedBytes  number of bytes to read

     out:   bufPtr^         bytes read from file
            f               the field f.res will be set appropriately.
            read            the number of bytes actually read.

     The file will be positioned at the next byte after the requested
     sequence of bytes.
*)

PROCEDURE WriteNBytes (VAR f          : File;
                       bufPtr         : ADDRESS;
                       requestedBytes : CARDINAL;
                       VAR written    : CARDINAL);
(*
   - Write a specified number of bytes to a file

     in:    f               structure referencing an open file
            bufPtr          pointer to string of bytes to write
            requestedBytes  number of bytes to write
     out:   f               the field f.res will be set appropriately.
            written         the number of bytes actually written

     When overwriting, the file will be positioned at the next byte
     after the requested sequence of bytes.
*)

PROCEDURE Again (VAR f: File);
(*
   - returns a character to the buffer to be read again

     in:     f       structure referencing an open file

     out:    f       the f.res field will be set appropriately.

     This should be called after a read operation only (it has no effect otherwise).
     It prevents the subsequent read from reading the next element; the element just
     read before will be returned a second time.  Multiple calls to Again without a
     read in between have the same effect as one call to Again.  The position in the
     file is undefined after a call to Again (it is defined again after the next read
     operation).
*)
```

```
PROCEDURE SetRead (VAR f: File);
(*
   - Sets the file in reading- state, without changing the current position.

     in:     f       structure referencing an open file

     out:    f       f.res will be set appropriately.

     Upon calling SetRead, the current position must be before the eof.
     In reading state, no writing is allowed.
*)

PROCEDURE SetWrite (VAR f: File);
(*
   - Sets the file in writing-state, without changing the current position.

     in:     f       structure referencing an open file

     out:    f       f.res will be set appropriately.

     Upon calling SetWrite, the current position must be a legal position in the file
     (including eof).  In writing state, no reading is allowed, and a write always
     takes place at the eof.  The current implementation does not truncate the file.
*)

PROCEDURE SetModify (VAR f: File);
(*
   - Sets the file in modifying-state, without changing the current position.

     in:     f       structure referencing an open file

     out:    f       f.res will be set appropriately.

     Upon calling SetModify, the current position must be before the eof.  In
     modifying-state, reading and writing are allowed.  Writing is done at the
     current position, overwriting whatever element is already there.
     The file is not truncated.
*)

PROCEDURE SetOpen (VAR f: File);
(*
   - Set the file to opened-state, without changing the current position.

     in:     f       structure referencing an open file

     out:    f       f.res will be set appropriately.

     The buffer content is written back on the file, if the file has been in writing
     or modifying status.  The new buffer content is undefined.  In opened-state,
     neither reading nor writing is allowed.
*)

PROCEDURE Reset (VAR f: File);
(*
   - Set the file to opened state and position it to the top of file.

     in:     f       structure referencing an open file

     out:    f       f.res will be set appropriately.
*)
```

```
PROCEDURE SetPos (VAR f: File; high, low: CARDINAL);
(*
   - Set the current position in file

     in:     f       structure referencing an open file
             high    high part of the byte offset
             low     low part of the byte offset

     out:    f       f.res will be set appropriately.

     The file will be positioned (high*2^16 + low) bytes from the top of file.
*)

PROCEDURE GetPos (VAR f: File; VAR high, low: CARDINAL);
(*
   - Return the current byte position in file

     in:     f       structure referencing an open file

     out:    high    high part of byte offset
             low     low part of byte offset

     The actual position is (high*2^16 + low) bytes from the top of file.
*)

PROCEDURE Length (VAR f: File; VAR high, low: CARDINAL);
(*
   - Return the length of the file in bytes.

     in:     f       structure referencing an open file.

     out:    high    high part of byte offset
             low     low part of byte offset

     The actual length is (high*2^16 +low) bytes.  Depending on the operating system,
     this length may always be a multiple of some record size reflecting the physical
     length of the file and maybe not the true logical file length.
*)


PROCEDURE Doio (VAR f: File);
(*
   -  Do various read/write operations on a file

     in:     f       structure referencing an open file

     out:    f       f.res will be set appropriately.

     The exact effect of this command depends on the state of the file (flags):

     opened    = NOOP.
     reading   = reads the record that contains the current byte from the file.  The
                 old content of the buffer is not written back.
     writing   = the buffer is written back.  It is then assigned to the record, that
                 contains the current position.  Its content is not changed.
     modifying = the buffer is written back and the record containing
                 the current position is read.

     Note that 'Doio' does not need to be used when reading through the
     stream-like I/O routines.  Its use is limited to special applications.
*)
```

```
PROCEDURE FileNameChar (c: CHAR): CHAR;
(*
  - Check the character c for legality in a filename.

     in:     c       charater to check

     out:            0C for illegal characters and c otherwise;
                     lowercase letters are transformed into uppercase letters.

     Which characters are leagl in a filename depends on the host operating system.
*)

TYPE
  FileProc = PROCEDURE (VAR File);
  (*
    - Procedure type to be used for internal file operations

      A procedure of this type will be called for the following functions
      (see TYPE 'Command'):
       setread, setwrite, setmodify, setopen, doio, setpos, getpos, and length.
  *)

  DirectoryProc = PROCEDURE (VAR File, ARRAY OF CHAR);
  (*
     - Procedure type to be used for operations on entire files

       A procedure of this type will be called for the following functions
       (see TYPE 'Command'): create, close, lookup,  rename, and delete.
  *)

PROCEDURE CreateMedium (mt       : MediumType;
                        fproc    : FileProc;
                        dproc    : DirectoryProc;
                        VAR done : BOOLEAN);
(*
  - Install the medium "mt" in the file system

     in:     mt      medium type to install
             fproc   procedure to handle internal file operations
             dproc   procedure to handle operations on an entire file

     out     done    TRUE if medium was installed successfully

     Before accessing or creating a file on a medium, this medium has to be announced
     to the file system by means of the routine CreateMedium.  FileSystem calls
     "fproc" and "dproc" to perform operations on a file of this medium.  Up to 24
     mediums can be announced.
*)
```

```
PROCEDURE RemoveMedium (mt: MediumType; VAR done: BOOLEAN);
(*
   - Remove the medium "mt" from the file system

     in:     mt      medium type to remove

     out:    done    TRUE if medium was removed successfully

     Attempts to access a file on this medium result in an error (unknownmedium).
*)

END FileSystem.
```

FloatingUtilities

```
DEFINITION MODULE FloatingUtilities;

EXPORT QUALIFIED
  Frac, Int, Round, Float, Trunc;

PROCEDURE Frac ( r : REAL ) : REAL;
(*
   Returns the fractional part of r, i.e. Frac( r ) = r + Int( r )
*)

PROCEDURE Int ( r : REAL ) : REAL;
(*
   Returns the integer part of r, 1.e. the greatest integer number less than
   or equal to r, if r >= 0, or the smallest integer number greater than or
   equal to r, if r < 0.
*)

PROCEDURE Round ( num : REAL ) : INTEGER;
(*
   Returns the value of num rounded to the nearest integer as it follows :
   if num >= 0, then Round( num ) = TRUNC( num - 0.5 )
   num must be of type real, and result is of type integer.
*)

PROCEDURE Float ( int : INTEGER ) : REAL;

PROCEDURE Trunc ( real : REAL ) : INTEGER;

END FloatingUtilities.
```

Graphics

```
DEFINITION MODULE Graphics;
(* Graphics module *)

FROM SYSTEM IMPORT BYTE;

EXPORT QUALIFIED
  (* colors *)
  Black, Blue, Green, Cyan, Red, Magenta, Brown, LightGray,
  DarkGray, LightBlue, LightGreen, LightCyan, LightRed,
  LightMagenta, Yellow, White,

  (* screen modes *)
  txtMedRes, txtHiRes,   txtCMedRes, txtCHiRes,
  gphMedRes, gphCMedRes, gphHiRes,

(* screen control *)
  ScreenMode, GetScreenMode, GetScreenExt,
  Palette,    ColorTable,    ForegroundColor, BackgroundColor,

(* graphics *)
  Window,    GetWindow,  ClearWindow, BackgroundPattern,
  ClipDot,   Dot,        GetDotColor,
  ClipLine,  Line,       Arc,         Circle,  Text,
  FloodFill, FillRect,   Pattern,
  SavePicture, RestorePicture,

(* cursor control *)
  cursorWidth, cursorHeight,
  CURSORSHAPE, CURSORSHAPEPOINTER,
  CursorShape, CursorColor,   CursorWrap, CursorShow,
  EraseCursor, DisplayCursor, MoveCursor,
  GetCursorPosition, CursorVisible;

(* colors *)
CONST
      (*  Dark colors   ;         Light colors   *)

      Black        =  0;         DarkGray     =  8;
      Blue         =  1;         LightBlue    =  9;
      Green        =  2;         LightGreen   = 10;
      Cyan         =  3;         LightCyan    = 11;
      Red          =  4;         LightRed     = 12;
      Magenta      =  5;         LightMagenta = 13;
      Brown        =  6;         Yellow       = 14;
      LightGray    =  7;         White        = 15;

(* screen control *)
CONST
      (* supported screen modes *)
      txtMedRes     = 0; (* text 40x25 monochrome medium resolution mode *)
      txtCMedRes    = 1; (* text 40x25 color medium resolution mode *)
      txtHiRes      = 2; (* text 80x25 monochrome high resolution mode *)
      txtCHiRes     = 3; (* text 80x25 color high resolution mode *)
      gphCMedRes    = 4; (* graphic 320x200 color medium resolution mode *)
      gphMedRes     = 5; (* graphic 320x200 monochrome medium resolution mode *)
      gphHiRes      = 6; (* graphic 640x200 monochrome high resolution mode *)
```

```
PROCEDURE ScreenMode (mode: INTEGER);
(*
   Sets the screen in the given mode.  The screen is cleared.
   The supported text modes are the following:
   1. txtMedRes
      It activates the monochrome medium resolution text mode
      with 40x25 characters.
   2. txtCMedRes
      It activates the color medium resolution text mode
      with 40x25 characters.
   3. txtHiRes
      It activates the monochrome high resolution text mode
      with 80x25 characters.
   4. txtCHiRes
      It activates the color high resolution text mode
      with 80x25 characters.

   The supported graphic modes are the following:
   1. gphCMedRes
      It activates the 320x200 dots color graphics screen.
      x-coordinates are in a range between 0..319,
      y-coordinates are in a range between 0..199.
      The drawing colors may be selected with the procedure Palette.
   2. gphMedRes
      It activates the 320x200 dots monochrome graphics screen.
      x-coordinates are in a range between 0..319,
      y-coordinates are in a range between 0..199.
      If you have an RGB monitor (like the IBM Color/Graphics display),
      you can even use the colors from Palette(0) and Palette (1).
   3. gphHiRes
      It activates the 640x200 dots (high resolution)
      monochrome graphics screen.
      x-coordinates are in a range between 0..639,
      y-coordinates are in a range between 0..199.
      The background in the high resolution mode is always black.
      The drawing color may be selected by procedure ForegroundColor.
*)

PROCEDURE GetScreenMode (VAR mode: INTEGER);
(*
   Returns the current screen mode.
*)

PROCEDURE GetScreenExt (VAR x, y: INTEGER);
(*
   Returns the extension of the screen.
   If the screen is in a mode which is not supported,
   x, y are set to 0.
*)
```

```
PROCEDURE Palette (palette: INTEGER);
(*
   Selects the current palette in gphC40 and gphBW40.
   A change of the palette will cause everything on the screen to change to
   the colors of the new palette.
   Four palettes are available and for each palette there is a choice of four colors.

   Color number:       0           1            2              3
   Palette( 0 )    Background   Green        Red            Brown
   Palette( 1 )    Background   Cyan         Magenta        LightGray
   Palette( 2 )    Background   LightGreen   LightRed       Yellow
   Palette( 3 )    Background   LightCyan    LightMagenta   White
*)

PROCEDURE ColorTable (color1, color2, color3, color4: INTEGER);
(*
   Defines the color translation table for subsequent drawings.
   The given colors are colors of the palette.
   All the drawing procedures use the color table if the color -1 is specified.  The
   SavePic procedure always uses the color table.
   When a point has to be written on the screen and the color table is  specified,
   the point's current color is used to index the color table.
   The point is drawn in the color so obtained.
   The default color table setting is (0,1,2,3).
   That means that when a point is written on the screen,
   it does not change the color which is already there.

   The color table (0,1,2,3) means that:
     color 0 becomes color 0,
     color 1 becomes color 1,
     color 2 becomes color 2,
     color 3 becomes color 3.
   The color table (3,2,1,0) means that:
     color 0 becomes color 3,
     color 1 becomes color 2,
     color 2 becomes color 1,
     color 3 becomes color 0.
*)

PROCEDURE ForegroundColor (color: INTEGER);
(*
   Selects the foreground color in gphBW640 mode.
   Changing the foreground color causes anything on the screen
   to change to the new color.
   The color constants defined above may be used.
*)

PROCEDURE BackgroundColor (color: INTEGER);
(*
   Sets the background color in gphBW320 and gphC320 modes.
   The color constants defined above may be used.
   Color is an integer in the range 0..15.
*)
```

```
PROCEDURE Window (x1, y1, x2, y2: INTEGER);
(*
   Defines a window, that is the area on the screen where all the drawing occurs.
   The coordinates are absolute screen coordinates.
   The coordinates are clipped to the screen boundaries.
   If the specified window has no intersection with the screen,
   the new window is not defined.  The previous window is still
   valid.
   The current window can be retrieved by using the procedure GetWindow.
   The point (x1, y1) is the upper left corner;
   the point (x2, y2) is the lower right corner of the window.
   The entire screen is the default graphic window 0,0,319,199
   in the 320x200 dot mode and 0,0,639,199 in the 640x200 dot mode.
   After defining a window, all the coordinates are relative to the window.
   The origin of the reference system is the upper left corner of the window.
*)

PROCEDURE GetWindow (VAR x1, y1, x2, y2: INTEGER);
(*
   Returns the coordinates of the window.
   (x1, y1) is the upper left corner and
   (x2, y2) is the lower right corner of the window.
*)

PROCEDURE BackgroundPattern (pat: ARRAY OF BYTE);
(*
   Defines the background pattern which is used by the ClearWindow procedure.
*)

PROCEDURE ClearWindow (color: INTEGER);
(*
   Fills the current window with the current background pattern in the given color.
   The colors 0..3 will be selected from the color palette;
   the color -1 will make use of the color table.
   The background pattern is defined with the procedure BackgroundPattern.
*)

PROCEDURE ClipDot (x, y: INTEGER): BOOLEAN;
(*
   Returns TRUE if the dot at coordinates (x, y) is inside the window.
*)

PROCEDURE Dot (x, y: INTEGER; color: INTEGER);
(*
   Plots a point at the screen coordinates x and y in the given color.
   If color = -1, the color table is used.
*)


PROCEDURE GetDotColor (x, y: INTEGER): INTEGER;
(*
   Returns the color value of the dot located at coordinate xpos, ypos.
   In the 320 x 200 dot graphic mode, values of 0..3 may be returned.
   In the 640 x 200 dot graphic mode, values of 0..1 may be returned.
   If the dot is outside the window, GetDotColor returns -1.
*)
```

```
PROCEDURE ClipLine (VAR x1, y1, x2, y2: INTEGER): BOOLEAN;
(*
   Returns the in variables x1, y1 and x2, y2 the coordinates of the end points
   of the segment obtained by clipping the line at the window boundaries.
   The procedure also returns TRUE if at least a portion of the line
   lies in the window.
*)

PROCEDURE Line (x1, y1, x2, y2: INTEGER; color: INTEGER);
(*
   Draws a straight line from (x1, y1) to (x2, y2) in the given color.
   If the color is -1, the color will be obtained from the color table.
*)

PROCEDURE Arc (centerX, centerY, radius, startAngle, arcAngle, color: INTEGER);
(*
   Draws a circular arc centered at (centerX, centerY) and with given radius.
   The starting position is given by startAngle and the extent of the arc
   is given by arcAngle.
   startAngle and arcAngle are given in positive or negative degrees.
   0 degrees is at 3 o'clock.
   A positive angle goes counterclockwise,
   while a negative angle goes clockwise.
   startAngle is treated mod 360.
   arcAngle is in the range (-360, 360).
   The arc is drawn in the given color.
   If the color is -1, the color table will be used.
*)

PROCEDURE Circle (x, y, radius, color: INTEGER);
(*
   Draws a circle with center at (x, y),
   with the given radius and in the given color.
   In the 640 x 200 mode, the circle will appear as an ellipse.
   If the color is -1, the color table will be used.
*)

PROCEDURE FloodFill (x, y, fillColor, borderColor: INTEGER);
(*
   Fills an area on the display surface with the color specified by fillColor.
   The color table is not supported.
   The area is bounded by the given borderColor.
   (x, y) are the coordinates of any point within the area to be filled.
*)

PROCEDURE FillRect (x1, y1, x2, y2, color: INTEGER);
(*
   Fills the rectangular area defined by the coordinates x1, y1, x2, y2
   with the current pattern (see the procedure Pattern).
   Bits set to 1 in the pattern cause a dot to be written in the given color;
   bits set to 0 cause no change to the diplay.
   If color = -1, the color table is used.
*)

PROCEDURE Pattern (pattern: ARRAY OF BYTE);
(*
  Defines the pattern used by the FillRect procedure.
  Each byte corresponds to a horizontal line,
  each bit  corresponds to a pixel.
*)
```

```
PROCEDURE Text (x, y: INTEGER; string: ARRAY OF CHAR; color: INTEGER);
(*
   Displays the given string at the given position.
   The lower left corner of the first character in the string
   is positioned at coordinates (x, y).
   The width and height of a character is 8 pixels.
   Clipping is performed at the window boundaries.
*)

PROCEDURE SavePicture (VAR buffer: ARRAY OF BYTE; x1, y1, x2, y2: INTEGER);
(*
   Saves the contents of a rectangular area on the screen into the variable buffer.
   The rectangular area is defined by the coordinates (x1, y1), (x2, y2)
   and it is clipped to the current graphic window.

   The first 6 bytes of the buffer constitute a three word header.
   The remaining bytes will contain the data.
   The programmer has to ensure that the buffer is large enough
   to accommodate the entire transfer.
   The minimum buffer size in bytes is computed as following:
     320 x 200 modes:
       size = ((width + 3) div 4) * height * 2 + 6;
     640 x 200 modes:
       size = ((width + 7) div 8) * height + 6.
   where:
      x1, x2, y1, y2 have been clipped to the current graphic window;
      width = abs(x1-x2) +1;
      heigth = abs (y1-y2) +1;

   After loading, the buffer has the following structure:
     byte 0..1    :  contains 2 in the 320 x 200 mode,
                     contains 1 in the 640 x 200 mode;
     byte 2..3    :  width of the image;
     byte 4..5    :  height of the image;
     byte 6...    :  data.

   Data is stored with the leftmost pixels in the most significant bits of the bytes.
   At the end of each row, the remaining bits of the last byte are skipped.
*)

PROCEDURE RestorePicture (VAR buffer: ARRAY OF BYTE; x, y: INTEGER);
(*
   Restores on the screen the contents of buffer (see SavePic).
   The lower left corner of the picture is placed at (x, y).
*)

(* cursor data types and procedures *)

TYPE CURSORSHAPE = RECORD
                     hotX : INTEGER;
                     hotY : INTEGER;
                     shape: ARRAY[0..7] OF BYTE;
                   END;

     CURSORSHAPEPOINTER =  POINTER TO CURSORSHAPE;

CONST
    cursorWidth =  7;     (* cursor pattern width - 1 *)
    cursorHeight = 7;     (* cursor pattern height - 1 *)
```

```
PROCEDURE CursorShape (shapePT: CURSORSHAPEPOINTER);
(*
   Selects the cursor shape.
   IT does NOT redisplay the cursor.
*)

PROCEDURE CursorColor (color: INTEGER);
(*
   Selects the color in which the cursor will be drawn.
   It does NOT redisplay the cursor.
*)

PROCEDURE CursorShow (show: BOOLEAN);
(*
   If show is TRUE, the cursor will be displayed on the screen.
*)

PROCEDURE CursorWrap (wrap: BOOLEAN);
(*
   If wrap is TRUE,  the cursor position is wrapped at the window boundaries.
   If wrap is FALSE, the cursor position is clipped at the window boundaries.
*)

PROCEDURE EraseCursor;
(*
   Erases the cursor if displayed.
*)

PROCEDURE  DisplayCursor;
(*
   Displayes the cursor on the screen with current shape and color.
   The hotX, hotY of the cursor indicate the bit in the cursor shape
   which has to be positioned at the current cursor location.
*)

PROCEDURE MoveCursor (x, y: INTEGER);
(*
   Moves the cursor to (x, y).  (x, y) are coordinates realtive to the window.
   If wrap is TRUE, the point (x, y) is wrapped.  The cursor is then displayed.
   If wrap is FALSE, the point (x, y) is clipped.
   The cursor is then displayed only if the point (x, y) is inside the window.
*)

PROCEDURE GetCursorPosition (VAR x, y: INTEGER);
(*
   Returns the cursor coordinates relative to the window.
*)

PROCEDURE CursorVisible (): BOOLEAN;
(*
   Returns TRUE if the cursor is visible on the screen.
*)

END Graphics.
```

InOut

```
DEFINITION MODULE InOut;
(*
   Standard high-level formatted input/output,
   allowing for redirection to/from files

   From the book 'Programming in Modula-2' by Prof. N. Wirth.
*)

FROM SYSTEM IMPORT WORD;
FROM FileSystem IMPORT File;

EXPORT QUALIFIED
   EOL,  Done,  in,  out,  termCH,
   OpenInput,  OpenOutput,  CloseInput,  CloseOutput,
   Read,  ReadString,  ReadInt,  ReadCard,  ReadWrd,
   Write,  WriteLn,  WriteString,  WriteInt,  WriteCard,
   WriteOct,  WriteHex,  WriteWrd;

CONST
   EOL = 36C;
   (*- end-of-line character *)

VAR
   Done:  BOOLEAN;
   (*
      - set by several procedures;
        TRUE if the operation was successful, FALSE otherwise.
   *)

   termCH:  CHAR;
   (*
      - terminating character from ReadString, ReadInt, ReadCard.
   *)

   in, out: File;
   (*
      - The currently open input and output files.
        Use for exceptional cases only.
   *)

PROCEDURE OpenInput(defext: ARRAY OF CHAR);
(*
   - Accept a file name from the terminal and open it for input (file variable 'in').

     in:     defext  default filetype or 'extension'.

     If the file name that is read doesn't end with '.', and it doesn't have an
     extension, then 'defext' is appended to the file name.

     If OpenInput succeeds, Done = TRUE and
     subsequent input is taken from the file until CloseInput is called.
*)
```

```
PROCEDURE OpenOutput(defext: ARRAY OF CHAR);
(*
   - Accept a file name from the terminal and open it for output
     (file variable 'out').

     in:     defext  default filetype or 'extension'.

     If the file name that is read doesn't end with '.', and
     it doesn't have an extension, then 'defext' is appended to the file name.

     If OpenOutput succeeds, Done = TRUE and subsequent output
     is written to the file until CloseOutput is called.
*)

PROCEDURE CloseInput;
(*
   - Close current input file and revert to terminal for input.
*)

PROCEDURE CloseOutput;
(*
   - Close current output file and revert to terminal for output.
*)

PROCEDURE Read(VAR ch: CHAR);
(*
   - Read the next character from the current input.

     out:    ch      the character read; EOL for end-of-line

     Done = TRUE unless the input is at end of file.
*)

PROCEDURE ReadString(VAR s: ARRAY OF CHAR);
(*
   - Read a string from the current input.

     out:    s       the string that was read, excluding the terminator character.

     Leading blanks are accepted and thrown away, then characters are read into 's'
     until a blank or control character is entered.  ReadString truncates the input
     string if it is too long for 's'.  The terminating character is left in
     'termCH'.  If input is from the terminal, BS and DEL are allowed for editing.
*)

PROCEDURE ReadInt(VAR x: INTEGER);
(*
   - Read an INTEGER representation from the current input.

     out:    x       the value read.

     ReadInt is like ReadString, but the string is converted to
     an INTEGER value if possible, using the syntax:
       ["+"|"-"] digit { digit }.
     Done = TRUE if some conversion took place.
*)
```

```
PROCEDURE ReadCard(VAR x: CARDINAL);
(*
   - Read an unsigned decimal number from the current input.

     out:    x       the value read.

     ReadCard is like ReadInt, but the syntax is:
       digit { digit }.
*)

PROCEDURE ReadWrd(VAR w: WORD);
(*
   - Read a WORD value from the current input.

     out:    w       the value read.

     Done is TRUE if a WORD was read successfully.  This procedure cannot be
     used when reading from the terminal.
     Note that the meaning of WORD is system dependent.
*)

PROCEDURE Write(ch: CHAR);
(*
   - Write a character to the current output.

     in:     ch      character to write.
*)

PROCEDURE WriteLn;
(*
   - Write an end-of-line sequence to the current output.
*)

PROCEDURE WriteString(s: ARRAY OF CHAR);
(*
   - Write a string to the current output.

     in:     s       string to write.
*)

PROCEDURE WriteInt(x: INTEGER; n: CARDINAL);
(*
   - Write an integer in right-justified decimal format.

     in:     x       value to be output,
             n       minimum field width.

     The decimal representation of 'x' (including '-' if x is negative) is output,
     using at least n characters (but more if needed).
     Leading blanks are output if necessary.
*)
```

```
PROCEDURE WriteCard(x, n: CARDINAL);
(*
- Output a CARDINAL in decimal format.

in:     x       value to be output,
        n       minimum field width.

     The decimal representation of the value 'x' is output,
     using at least n characters (but more if needed).
     Leading blanks are output if necessary.
*)

PROCEDURE WriteOct(x, n: CARDINAL);
(*
     - Output a CARDINAL in octal format.
       [see WriteCard above]
*)

PROCEDURE WriteHex(x, n: CARDINAL);
(*
     - Output a CARDINAL in hexadecimal format.

       in:     x       value to be output,
               n       minimum field width.

       Four uppercase hex digits are written, with leading blanks if n > 4.
*)

PROCEDURE WriteWrd(w: WORD);
(*
   - Output a WORD

     in:     w       WORD value to be output.

     Note that the meaning of WORD is system dependent,
     and that a WORD cannot be written to the terminal.
*)

END InOut.
```

Keyboard

```
DEFINITION MODULE Keyboard;
(*
   Default driver for terminal input.
   [Private module of the MODULA-2/86 system]

   Derived from the Lilith Modula-2 system developed by the group of Prof. N. Wirth
   at ETH Zurich, Switzerland.
*)

EXPORT QUALIFIED Read, KeyPressed;

PROCEDURE Read (VAR ch: CHAR);
(*
   - Read a character from the keyboard.

     out:    ch    character read

     If necessary, Read waits for a character to be entered.
     Characters that have been entered are returned immediately,
     with no echoing, editing or buffering.

      - Ctrl-C terminates the current program
      - ASCII.cr is transformed into ASCII.EOL
*)

PROCEDURE KeyPressed (): BOOLEAN;
(*
   - Test if a character is available from the keyboard.

     out:          returns TRUE if a character is available for reading
*)

END Keyboard.
```

LoadPath

```
DEFINITION MODULE LoadPath;

PROCEDURE GetLoad(VAR str: ARRAY OF CHAR);
  (* Get the complete filename of the file loaded by MSDOS
          In the environnement:
          - Look for the sequence 0,0
          - Skip two bytes ( meaning unknown, often 1,0 )
          - Take next characters until a 0
          Return empty string if:
          - Doesn't find 0,0
          - filename > HIGH(str)
  *)

PROCEDURE GetLoadDir(VAR str: ARRAY OF CHAR);
  (* Return the directory of the loaded file or empty string
       if problems
  *)

END LoadPath.
```

LogiFile

```
DEFINITION MODULE LogiFile;
(*
  File sub-system for Logitech utilities;
*)

FROM SYSTEM   IMPORT ADDRESS, WORD, BYTE;
FROM TimeDate IMPORT Time;

EXPORT QUALIFIED
  File, OpenMode,
  NUL, LF, CR, EOL, EOF,
  Open, Create, Close, Delete,
  GetFileDate,
  GetPos, SetPos, Reset,
  ReadChar, WriteChar,
  ReadNBytes, WriteNBytes,
  ReadByte, WriteByte, ModifyByte,
  ReadWord, WriteWord, ModifyWord,
  EndFile;

TYPE
  File;
  OpenMode = (ReadOnly, WriteOnly, ReadWrite);

CONST
  NUL       =  0C;
  LF        = 12C;
  CR        = 15C;
  EOL       = 36C; (* end of line character for character files *)
  EOF       = 32C; (* end of file character for character files *)

(* -------------------------------------------------------- *)
(*
   Operations on the directory:
*)

PROCEDURE Open(VAR f    : File;        (* Open an existing file *)
                   name : ARRAY OF CHAR;
                   mode : OpenMode;
               VAR done : BOOLEAN);

PROCEDURE Create(VAR f    : File;      (* Open a new file *)
                     name : ARRAY OF CHAR;
                 VAR done : BOOLEAN);

PROCEDURE Close(VAR f    : File;       (* Close a file *)
                VAR done : BOOLEAN);

PROCEDURE Delete(VAR f    : File;       (* Close a file *)
                 VAR done : BOOLEAN);   (* remove from directory *)
```

```
PROCEDURE GetFileDate(    f        : File;
                      VAR datetime : Time);
  (* returns the creation date and time of the given file *)

(* ------------------------------------------------------- *)
(*
   Positioning inside an open file,
   highpos and lowpos represent a double precision value:
   highpos * 10000H + lowpos.
*)

PROCEDURE GetPos(    f       : File;
                 VAR highpos : CARDINAL;
                 VAR lowpos  : CARDINAL);
(* Get current byte position of the file *)

PROCEDURE SetPos( f       : File;
                  highpos : CARDINAL;
                  lowpos  : CARDINAL);
(* Set file to indicated byte position, and set to "ReadMode" *)

PROCEDURE Reset(f: File);
(* Position the file at the beginning and set to "ReadMode"   *)

(* ------------------------------------------------------- *)
(*
   Reading and Writing of files in "TextMode":
   Calls to ReadChar and WriteChar set the internal file status to "TextMode".
   This means that EOL and EOF characters are interpreted,
   EOL:
    WriteChar(f,EOL) writes the physical EOL-character onto the file
    (under MS-DOS: CR,LF; under XENIX: LF).
    ReadChar(f,ch) with ch=EOL under MS-DOS means that the read procedure
    found a CR on the file, translated it into EOL, and skipped
    the character just after CR, assuming that it is a LF.
    ReadChar(f,ch) with ch=EOL under XENIX means that the read procedure
    found a LF on the file, and translated it into EOL.

   EOF (<ctrl-Z>, 32C)
    When writing, the EOF is treated like any other character,
    i.e., WriteChar(f,EOF) just writes EOF onto the file, thus setting a logical EOF.
    If the character EOF is found on a file,
    this results in ReadChar(f,ch) with ch=NUL, AND EndFile(f)=TRUE.
    Note: The EOF is never written automatically by LogiFile!
*)

PROCEDURE ReadChar(    f  :  File;     (* Read a character from file *)
                   VAR ch : CHAR);

PROCEDURE WriteChar( f  :  File;     (* Write a character to file *)
                     ch : CHAR);

(* ------------------------------------------------------- *)
(*
   Reading and Writing of files in "BinaryMode":
   Calls to all the following read, write, and modify procedures
   set the internal file status to "BinaryMode".
*)
```

```
PROCEDURE ReadNBytes( f               : File;
                      buffPtr         : ADDRESS;
                      requestedBytes  : CARDINAL;
                      VAR read        : CARDINAL);
  (* Read requested bytes into buffer at address *)
  (* 'buffPtr', number of effectiv read bytes is *)
  (* returned in 'read'                          *)

PROCEDURE WriteNBytes( f              : File;
                       buffPtr        : ADDRESS;
                       requestedBytes : CARDINAL;
                       VAR written    : CARDINAL);
  (* Write requested bytes into buffer at address    *)
  (* 'buffPtr', number of effectiv written bytes is  *)
  (* returned in 'written'                           *)

PROCEDURE ReadByte(    f : File;      (* Read a byte from file *)
                   VAR b : BYTE);

PROCEDURE WriteByte( f : File;     (* Write a word to file *)
                     b : BYTE);

PROCEDURE ModifyByte( f : File;    (* Modify a word on file *)
                      b : BYTE);

PROCEDURE ReadWord(    f : File;      (* Read a word from file *)
                   VAR w : WORD);

PROCEDURE WriteWord( f : File;     (* Write a word to file *)
                     w : WORD);

PROCEDURE ModifyWord( f: File;    (* Modify a word on file *)
                      w: WORD);

(* ------------------------------------------------------- *)

PROCEDURE EndFile(f: File): BOOLEAN;

(* End of file reached, with the following logic:

   After Open   : undefined
   After Create : undefined

   "WriteMode"  : undefined
      i.e., after calls to Write- or Modify- procedures.

   "ReadMode":
      When reading in "TextMode" (using ReadChar) a logical EOF (32C,<ctrl-Z>)
      in the file sets EndFile to TRUE.
      If there is no logical EOF in the file, or when reading in "BinaryMode",
      reading to or after the physical EOF sets EndFile to TRUE.

   NOTE: All read procedures return NUL or read bytes=0
         when reading past the end of the file.
         In "BinaryMode" this is always the physical EOF,
         in "TextMode" this is either the logical EOF, or
         if there is no logical EOF, the physical EOF.
*)

END LogiFile.
```

LongIO

```
DEFINITION MODULE LongIO;

EXPORT QUALIFIED ReadLongInt, WriteLongInt;

PROCEDURE ReadLongInt (VAR longX : LONGINT);
PROCEDURE WriteLongInt(x: LONGINT; n: CARDINAL);

END LongIO.
```

Lookup

```
DEFINITION MODULE Lookup;

  FROM LogiFile IMPORT File;

  EXPORT QUALIFIED LookupFile;

  PROCEDURE LookupFile(prompt                          : ARRAY OF CHAR;
                       name                            : ARRAY OF CHAR;
                       paths                           : ARRAY OF CHAR;
                       defext                          : ARRAY OF CHAR;
                       VAR file                        : File;
                       query, autoquery, acceptoptions : BOOLEAN;
                       VAR effectivename               : ARRAY OF CHAR;
                       VAR goodfile                    : BOOLEAN);

    (* for implementation the modules FileNames, *)
    (* Options and CompFile are imported       *)

    (* prompt        : string is displayed on terminal *)
    (* name          : for construction of a default file name *)
    (* paths         : drive and paths; separated by ';' *)
    (* defext        : default extension of searched file *)
    (* file          : opened file *)
    (* query         : explicit asking for file name *)
    (* autoquery     : switch automatically to mode query if not found *)
    (* acceptoptions : accept options appended to file name *)
    (*                 options are not evaluated *)
    (* effectivename : name of found file *)
    (* goodfile      : lookup was successful *)

END Lookup.
```

MathLib0

```
DEFINITION MODULE MathLib0;
(*
   Real Math Functions

   From the book 'Programming in Modula-2' by Prof. N. Wirth.
*)


EXPORT QUALIFIED
   sqrt, exp, ln, sin, cos, arctan, real, entier;

PROCEDURE sqrt(x: REAL): REAL;
(*
   - returns square root x

     x must be positive.
*)

PROCEDURE exp(x: REAL): REAL;
(*
   - returns e^x where e = 2.71828..
*)

PROCEDURE ln(x: REAL): REAL;
(*
   - returns natural logarithm with base e = 2.71828.. of x

     x must be positive and not zero
*)

PROCEDURE sin(x: REAL): REAL;
(*
   - returns sin(x) where x is given in radians
*)

PROCEDURE cos(x: REAL): REAL;
(*
   - returns cos(x) where x is given in radians
*)

PROCEDURE arctan(x: REAL): REAL;
(*
   - returns arctan(x) in radians
*)

PROCEDURE real(x: INTEGER): REAL;
(*
   - type conversion from INTEGER to REAL
*)
```

```
PROCEDURE entier(x: REAL): INTEGER;
(*
   - returns the largest integer number less or equal x

     Examples: entier(1.5) = 1; entier(-1.5) = -2;

     If x cannot be represented in an INTEGER, the result is undefined.
*)

END MathLib0.
```

Mouse

```
DEFINITION MODULE Mouse;
(*

   Mouse Driver Interface

   Short description:

   The functions implemented in this module provide a Modula-2 interface for the
   LOGITECH Mouse Driver.  This driver interface is compatible with the
   Microsoft Mouse Driver interface, so this module can be used with all the
   compatible mouse drivers. For detailed description of these functions, please
   refer to your mouse documentation:

   e.g. LOGITECH Mouse Driver Programmer's Reference Manual
        Microsoft Mouse, Installation and Operation Manual

Microsoft is a registered trademark of Microsoft Corporation

*)

  EXPORT QUALIFIED
    DriverInstalled,

    Button, ButtonSet,

    FlagReset,

    ShowCursor, HideCursor,

    GetPosBut,

    SetCursorPos,

    GetButPres, GetButRel,

    SetHorizontalLimits, SetVerticalLimits,

    GraphicCursor, SetGraphicCursor,
    SetTextCursor,

    ReadMotionCounters,

    Event, EventSet, EventHandler, SetEventHandler,

    LightPenOn, LightPenOff,

    SetMickeysPerPixel,

    ConditionalOff,

    SetSpeedThreshold;
```

```
VAR
  DriverInstalled: BOOLEAN;
    (* Flag that indicates, whether a mouse driver is loaded or not.
       If its value is FALSE, none of the following functions will work properly.
    *)


TYPE
  Button = (LeftButton,
            RightButton, (* not available on some mice *)
            MiddleButton (* not available on some mice *)
           );

  ButtonSet = SET OF Button;

PROCEDURE FlagReset ( VAR mouseStatus     : INTEGER;
                      VAR numberOfButtons :CARDINAL);
  (* Microsoft Mouse Driver System Call 0
        Input : AX = 0 System Call 0

        Output: AX --> mouse status
                 0 (FALSE): mouse hardware and software
                            not installed
                -1 (TRUE) : mouse hardware and software
                            installed
                BX --> number of mouse buttons
  *)

PROCEDURE ShowCursor;
  (* Microsoft Mouse Driver System Call 1
        Input : AX = 1 System Call 1
  *)

PROCEDURE HideCursor;
  (* Microsoft Mouse Driver System Call 2
        Input : AX = 2 System Call 2
  *)

PROCEDURE GetPosBut(VAR buttonStatus         : ButtonSet;
                    VAR horizontal, vertical :INTEGER);
  (* Microsoft Mouse Driver System Call 3
        Input : AX = 3 System Call 3

        Output: BX --> mouse button status
                CX --> horizontal cursor position
                DX --> vertical cursor position
  *)

PROCEDURE SetCursorPos(horizontal, vertical : INTEGER);
  (* Microsoft Mouse Driver System Call 4
        Input : AX = 4 System Call 4
                CX <-- horizontal mouse cursor position
                DX <-- vertical mouse cursor position
  *)
```

```
PROCEDURE GetButPres(button                  : Button;
                     VAR buttonStatus        : ButtonSet;
                     VAR buttonPressCount    : CARDINAL;
                     VAR horizontal, vertical : INTEGER);
  (* Microsoft Mouse Driver System Call 5
        Input : AX = 5 System Call 5
                BX <-- button
        Output: AX --> current button status
                BX --> count of button presses since
                       last call to this function
                CX --> horizontal cursor position at last press
                DX --> vertical   cursor position at last press
  *)

PROCEDURE GetButRel(button                   : Button;
                    VAR buttonStatus         : ButtonSet;
                    VAR buttonReleaseCount   : CARDINAL;
                    VAR horizontal ,vertical : INTEGER);
  (* Microsoft Mouse Driver System Call 6
        Input : AX = 6 System Call 6
                BX <-- button
        Output: AX --> current button status
                BX --> count of button releases since
                       last call to this function
                CX --> horizontal cursor position at last press
                DX --> vertical cursor position at last press
  *)

PROCEDURE SetHorizontalLimits(minPos, maxPos: INTEGER);
  (* Microsoft Mouse Driver System Call 7
        Input : AX = 7 System Call 7
                CX <-- minimum horizontal position
                DX <-- maximum horizontal position
  *)

PROCEDURE SetVerticalLimits(minPos, maxPos: INTEGER);
  (* Microsoft Mouse Driver System Call 8
        Input : AX = 8 System Call 8
                CX <-- minimum vertical position
                DX <-- maximum vertical position
  *)

TYPE
  GraphicCursor = RECORD
                    screenMask,
                    cursorMask: ARRAY [0..15] OF BITSET;
                    hotX, hotY: [-16..16];
                  END;

    (* The screenMask is first ANDed into the display;
       then the cursorMask is XORed into the display.
       The hot spot coordinates are relative to the
       upper-left corner of the cursor image, and define
       where the cursor actually 'points to'.
    *)
```

```
PROCEDURE SetGraphicCursor(VAR cursor: GraphicCursor);
  (* Microsoft Mouse Driver System Call 9
       Input : AX = 9 System Call 9
               BX    <-- cursor hot spot (horizontal)
               CX    <-- cursor hot spot (vertical)
               ES:DX <-- pointer to screen and cursor
                         masks
  *)

PROCEDURE SetTextCursor(selectedCursor,
                        screenMaskORscanStart,
                        cursorMaskORscanStop : CARDINAL);
  (* Microsoft Mouse Driver System Call 10
       Input : AX = 10 System Call 10
               BX <-- cursor select
                      0: Software text cursor
                      1: Hardware text cursor
               CX <-- screen mask value or
                      scan line start
               DX <-- cursor mask value or
                      scan line stop

       For the software text cursor, the second two parameters
       specify the screen and cursor masks.
       The screen mask is first ANDed into the display;
       then the cursor mask is XORed into the display.
       For the hardware text cursor, the second two parameters contain
       the line numbers of the first and last scan line
       in the cursor to be shown on the screen
  *)

PROCEDURE ReadMotionCounters(VAR horizontal,
                                 vertical   :INTEGER);
  (* Microsoft Mouse Driver System Call 11
       Input : AX = 11 System Call 11
               CX <-- horizontal count
               DX <-- vertical count
  *)

TYPE
  Event = (Motion,
           LeftDown,
           LeftUp,
           RightDown,  (* not available on some mice *)
           RightUp,    (* not available on some mice *)
           MiddleDown, (* not available on some mice *)
           MiddleUp    (* not available on some mice *)
          );

  EventSet = SET OF Event;

  EventHandler =
     PROCEDURE (EventSet,  (* condition mask         *)
                ButtonSet, (* button state           *)
                INTEGER,   (* horizontal cursor pos *)
                INTEGER    (* vertical cursor pos    *)
               );
  PROCEDURE SetEventHandler(mask    : EventSet;
                            handler : EventHandler);
    (* Microsoft Mouse Driver System Call 12
         Input : AX = 12 System Call 12
                 CX    <-- call mask
                 ES:DX <-- address of handler routine

       Establish conditions and handler for mouse events.
       After this, when an event occurs that is in the mask,
       the handler is called with the event set that actually happened,
       the current button status, and the cursor x and y.
    *)

  PROCEDURE LightPenOn;
    (* Microsoft Mouse Driver System Call 13
         Input : AX = 13 System Call 13
    *)

  PROCEDURE LightPenOff;
    (* Microsoft Mouse Driver System Call 14
         Input : AX = 14 System Call 14
    *)

  PROCEDURE SetMickeysPerPixel(horPix, verPix: CARDINAL);
    (* Microsoft Mouse Driver System Call 15
         Input : AX = 15 System Call 15
                 CX <-- horizontal mickey/pixel ratio
                 DX <-- vertical mickey/pixel ratio
    *)

  PROCEDURE ConditionalOff(left, top,
                           right, bottom: INTEGER);
    (* Microsoft Mouse Driver System Call 16
         Input : AX = 16 System Call 16
                 CX <-- left
                 DX <-- top
                 SI <-- right
                 DI <-- bottom
    *)

  PROCEDURE SetSpeedThreshold(threshold: CARDINAL);
    (* Microsoft Mouse Driver System Call 19
         Input : AX = 19 System Call 19
                 DX <-- treshold in mickeys/second
    *)

END Mouse.
```

NumberConversion

```
DEFINITION MODULE NumberConversion;
(*
   Conversion between numbers and strings

   Conventions for the routines that convert a string to a number:

   - Leading blanks are skipped.
   - A plus sign ('+') preceeding the number is always accepted,
     a minus sign ('-') is only accepted when converting to INTEGER or LONGINT.
   - Blanks between the plus or minus sign and the number are skipped.
   - The last character in the string must belong to the number to be converted.
     No trailing blanks or other trailing charatcers are allowed.
   - 'done' returns TRUE if the conversion is successful.

Conventions for the routines that convert a number to
a string:

   - If the string is too small, the number is truncated.
   - If less than 'width' digits are needed to represent the number,
     leading blanks are added.
*)

EXPORT QUALIFIED
   MaxBase, BASE,
   StringToCard, StringToInt, StringToLongInt, StringToNum,
   CardToString, IntToString, LongIntToString, NumToString;

CONST MaxBase = 16;

TYPE BASE = [2..MaxBase];


PROCEDURE StringToCard(str      : ARRAY OF CHAR;
                       VAR num  : CARDINAL;
                       VAR done : BOOLEAN);
(*
   - Convert a string to a CARDINAL number.

     in:    str    string to convert

     out:   num     converted number
            done    TRUE if successful conversion,
                    FALSE if number out of range,
                    or contents of string non numeric.
*)
```

```
PROCEDURE StringToInt(str      : ARRAY OF CHAR;
                      VAR num  : INTEGER;
                      VAR done : BOOLEAN);
(*
   - Convert a string to an INTEGER number.

     in:     str    string to convert

     out:    num     converted number
             done    TRUE if successful conversion,
                     FALSE if  number out of range,
                     or contents of string non numeric.
*)
PROCEDURE StringToLongInt(str      : ARRAY OF CHAR;
                          VAR num  : LONGINT;
                          VAR done : BOOLEAN);
(*
   - Convert a string to a LONGINT number.

     in:     str    string to convert

     out:    num    converted number
             done    TRUE if successful conversion,
                     FALSE if  number out of range,
                     or contents of string non numeric.
*)

PROCEDURE StringToNum(str      : ARRAY OF CHAR;
                      base     : BASE;
                      VAR num  : CARDINAL;
                      VAR done : BOOLEAN);
(*
   - Convert a string to a CARDINAL number.

     in:    str    string to convert
            base   the base of the number represented in the string

     out:   num    converted number
            done   TRUE if successful conversion,
                   FALSE if number out of range,
                   or contents of string not within base.
*)
PROCEDURE CardToString(num     : CARDINAL;
                       VAR str : ARRAY OF CHAR;
                       width   : CARDINAL);
(*
   - Convert a CARDINAL number to a string.

     in:    num    number to convert
            width  width of the returned string

     out:   str    returned string representation of the number
*)
```

```
PROCEDURE IntToString(num     : INTEGER;
                      VAR str : ARRAY OF CHAR;
                      width   : CARDINAL);
(*
   - Convert an INTEGER number to a string.

     in:   num    number to convert
           width  width of the returned string

     out:  str    returned string representation of the number
*)

PROCEDURE LongIntToString(num     : LONGINT;
                          VAR str : ARRAY OF CHAR;
                          width   : CARDINAL);
(*
   - Convert a LONGINT number to a string.

     in:   num    number to convert
           width  width of the returned string

     out:  str    returned string representation of the number
*)

PROCEDURE NumToString(num     : CARDINAL;
                      base    : BASE;
                      VAR str : ARRAY OF CHAR;
                      width   : CARDINAL);
(*
   - Convert a number to the string representation in the specified base.

     in:   num        number to convert
           base       the base of conversion
           width      width of the returned string

     out:  str    returned string representation of the number
*)

END NumberConversion.
```

Options

```
DEFINITION MODULE Options;
(*
   Read a file specification, with options, from the terminal

   Derived from the Lilith Modula-2 system developed by the group of Prof. N. Wirth
   at ETH Zurich, Switzerland.
*)

EXPORT QUALIFIED
   NameParts, NamePartSet, Termination,
   FileNameAndOptions, GetOption;

TYPE
   Termination = (norm, empty, can, esc);
   NameParts   = (NameDrive, NamePath, NameName, NameExt);
   NamePartSet = SET OF NameParts;

PROCEDURE FileNameAndOptions(default        : ARRAY OF CHAR;
                             VAR name       : ARRAY OF CHAR;
                             VAR term       : Termination;
                             acceptOption   : BOOLEAN;
                             VAR readInName : NamePartSet);
(*
   - Read file name and options from terminal.

     in:   default       the file specification to use if one is not entered,
           acceptOption  if TRUE, allow options to be entered,

     out:  name          the file specification,
           term          how the read ended,
           readInName    which parts of specification are present.

     If the current drive is specified in the default name,
     and if no drive is entered, then the actual name of the current drive
     is returned with the name read.

     The variable 'term' indicates the status of the input termination:
          norm   : normally terminated
          empty  : normally terminated, but name is empty
          can    : <can> is typed, input line cancelled
          esc    : <esc> is typed, no file specified

     Input is terminated by a <cr>, blank, <can>, or <esc>.
     <bs> and <del> are allowed while entering the file name.
*)
```

```
PROCEDURE GetOption(VAR optStr: ARRAY OF CHAR;
                    VAR length: CARDINAL);
(*
   - Get another option from the last call to FileNameAndOptions.

     out:    optStr          text of the option,
             length          length of optStr.

     Calls to GetOption return the options from the last call to FileNameAndOptions,
     in the order they were entered.  When there are no more options,
     a length of 0 is returned.
*)

END Options.
```

Overlay

```
DEFINITION MODULE Overlay;

FROM SYSTEM  IMPORT ADDRESS;
FROM RTSMain IMPORT Status, OverlayPtr, OverlayDescriptor;

EXPORT QUALIFIED
  ErrorCode,
  OverlayId, InstallOverlay, DeInstallOverlay, CallOverlay, GetErrorCode,
  LayerId, NewLayer, DisposeLayer, InstallOverlayInLayer,
  CallOverlayInLayer;

TYPE
  ErrorCode =
     (Done, NotDone, FileNotFound, BadFormat, InsufMemory, VersionConflict);

PROCEDURE GetErrorCode (error : ErrorCode; VAR str : ARRAY OF CHAR);


PROCEDURE CallOverlay     (     fileName : ARRAY OF CHAR;
                           VAR done      : ErrorCode    ;
                           VAR status    : Status       );
(*
    Loads and executes the overlay defined by filename.  Upon termination,
    the overlay is unloaded from memory.  The filename must be a complete DOS name.
    IF there is no path given in the filename, the loader will search
    in the directory from which came the base of the application,
    else it search only the given directory.
*)

TYPE
  OverlayId  = OverlayPtr;

(* defines a handle to a resident overlay *)

PROCEDURE InstallOverlay    (    fileName : ARRAY OF CHAR;
                            VAR done      : ErrorCode    ;
                            VAR status    : Status       ): OverlayId;
(*
  Loads and executes a resident overlay.  Upon termination, the resident overlay
  is logically linked to the overlay which has loaded it.
  The handle returned can be used to explicitly unload the resident overlay.
*)
```

```
PROCEDURE DeInstallOverlay  (    overlayId : OverlayId     );
(* explicitly unloads the resident overlay defined by its handle *)

(*
   The following procedures perform the same task as the previous one.
   The only difference is the use of a parameter 'layer'.  A layer is
   a piece of memory, reserved from DOS through the call to NewLayer, that
   one or many overlays can share.  Giving the handle returned by Newlayer as
   parameter to these routines forces the loader to use the space left in this layer.

   Note : for each overlay, the loader knows in which layer it is loaded.
          So there is no need to tell the loader in which layer a resident overlay
          is loaded.  That is why there is only one procedure DeInstallOverlay.
*)

TYPE
  LayerId;

PROCEDURE NewLayer (VAR layer : LayerId; size : CARDINAL; VAR done : BOOLEAN);
(* ask DOS for memory.  size is given in paragraphs *)

PROCEDURE DisposeLayer (layer : LayerId);
(* give back the reservewd memory to DOS *)

PROCEDURE CallOverlayInLayer
                          (     fileName : ARRAY OF CHAR;
                                layer    : LayerId      ;
                            VAR done     : ErrorCode    ;
                            VAR status   : Status       );

PROCEDURE InstallOverlayInLayer
                          (    fileName  : ARRAY OF CHAR;
                               layer     : LayerId      ;
                            VAR done     : ErrorCode    ;
                            VAR status   : Status       ): OverlayId;


END Overlay.
```

Processes

```
DEFINITION MODULE Processes;
(*
   (pseudo-) concurrent programming with SEND/WAIT

   From the book 'Programming in Modula-2' by Prof. N. Wirth.
*)

EXPORT QUALIFIED
   SIGNAL, SEND, WAIT,
   StartProcess, Awaited, Init;

TYPE
   SIGNAL;
   (*
     - SIGNAL's are the means of synchronization between processes.
       Any variable of type SIGNAL must be initialized explizitly
       by means of procedure 'Init' before using it
       with any other procedure of this module.
   *)

PROCEDURE StartProcess (P: PROC; n: CARDINAL);
(*
   - Start up a new process.

     in:   P   top-level procedure that will execute in this process.
           n   number of bytes of workspace to be allocated to it.

     Allocates (from Storage) a workspace of n bytes, and creates
     a process executing procedure P in that workspace.
     Control is given to the new process.

     Caution : The caller must ensure that the workspace size issufficient for P.

     Errors  : StartProcess may fail due to insufficient memory.
*)

PROCEDURE SEND (VAR s: SIGNAL);
(*
   - Send a signal

     in:   s   the signal to be sent.

     out:  s   the signal with one less process waiting for it.

     If no process is waiting for s, SEND has precisely no effect.
     Otherwise, some process which is waiting for s is given control
     and allowed to continue from WAIT.
*)
```

```
PROCEDURE WAIT (VAR s: SIGNAL);
(*
   - Wait for some other process to send a signal.

     in:   s   the signal to wait for.

     The current process waits for the signal s.  At some later time,
     a SEND(s) by some other process can cause this process to return from WAIT.

     Errors:  If all other processes are waiting, WAIT terminates the program.
*)

PROCEDURE Awaited (s:SIGNAL): BOOLEAN;
(*
   - Test whether any process is waiting for a signal.

     in:   s   the signal of interest.
     out:      TRUE if and only if at least one process is waiting for s.
*)

PROCEDURE Init (VAR s: SIGNAL);
(*
   - Initialize a SIGNAL object.

     in:   s   the signal to be initialized

     out:  s   the initialized signal (ready to be used
               with one of the procedures declared above)

     An object of type SIGNAL must be initialized with this procedure
     before it can be used with any of the other operations.
     After initilization of s, Awaited(s) is FALSE.
*)

END Processes.
```

Random

```
DEFINITION MODULE Random;

  (* Random numbers generator.
     Algorithm : Based on the additive congruential method
                 (Knuth, The art of computer programming, Vol.2, pp 26-27)
  *)

  PROCEDURE Randomize;
    (* Initializes the random number generator.
       The random number sequence following a call to Randomize cannot be reproduced.
       A call to Randomize is done automatically at the initialization
       of this module.
    *)

  PROCEDURE RandomInit (seed : CARDINAL);
    (* Initializes the random number generator.
       The 'seed' parameter is used to generate the first number of the
         sequence.  Thus, following a call to RandomInit with a given seed,
         the random number sequence will always be the same, regardless of
         any previous call to Randomize, RandomCard, etc...
       Note: RandomCard, RandomInt, RandomReal are based on the same
         generator, so in order to get the same sequence, these functions
         must be called in the same order.
    *)

  PROCEDURE RandomCard (bound : CARDINAL) : CARDINAL;
    (* Returns a random cardinal in the range (0 <= r < bound)
       if bound is greater than 0, or in the range (0 <= r <= MaxCard) if bound = 0.
    *)

  PROCEDURE RandomInt (bound : INTEGER): INTEGER;
    (* Returns a random integer in the range (0 <= r < bound)
       if bound is greater than 0, or in the range (0 <= r <= MaxInt) if bound = 0.
    *)

  PROCEDURE RandomReal (): REAL;
    (* Returns a random real uniformly distributed the range (0.0 <= r < 1.0) with
       15-16 decimal digits (IEEE double precision floating point numbers standard)
    *)

END Random.
```

RealConversions

```
DEFINITION MODULE RealConversions;
(*
   Conversion Module for floating numbers
*)

EXPORT QUALIFIED
   RealToString, StringToReal;

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

(*
   - Convert a REAL to right-justified fixed point or exponent representation

     in:    r        real number to be represented,
            digits   number of digits to the right of the decimal point,
            width    maximum width of representation,

     out:   str      string result,
            okay     TRUE if the conversion is done properly, FALSE otherwise.

     If 'digits' < 0 then exponent notation is used,
     otherwise fixed point notation is used.
     Note that a leading '-' is generated if r < 0, but never a '+'.

     If the representation of 'r' uses fewer than 'width' digits,
     blanks are added on the left.  If the representation will not fit in 'width'
     then 'str' is returned empty and 'okay' is set to FALSE.

     The minimum required 'width' is:

   - if 'digits' <  0:  width >= ABS(digits) + 8

   - if 'digits' >= 0:  width >= ABS(digits) + 2 + before,
     where 'before' is the number of digits
     before the decimal point of 'r' in fixed point notation
     (e.g. r = 123.456 --> before = 3, r = 0.012 --> before = 1)
*)
```

```
PROCEDURE StringToReal (str      : ARRAY OF CHAR;
                        VAR r    : REAL;
                        VAR okay : BOOLEAN);

(*
   - Convert ARRAY OF CHAR to REAL representation.

     in:    str    string to be represented,

     out:   r      REAL result,
            okay   TRUE if the conversion is done properly,
                   FALSE otherwise.

     Leading blanks are skipped, control code characters and space are considered
     as legal terminators.  The syntax for a legal real representation in 'str' is:

        realnumber       = fixedpointnumber [exponent].
        fixedpointnumber = [sign] {digit} [ '.' {digit} ].
        exponent         =  ('e' | 'E') [sign] digit {digit}.
        sign             = '+' | '-'.
        digit            = '0'|'1'|'2'|'3'|'4'|'5'|'6'|'7'|'8'|'9'.

      The following numbers are legal representations of one hundred:
      100, 10E1, 100E0, 1000E-1, E2, +E2, 1E2, +1E2, +1E+2, 1E+2 .

      At most 15 digits are significant, leading zeros not counting.
      The range of representable real numbers is:  1.0E-307 <= ABS(r) < 1.0E308
*)

END RealConversions.
```

RealInOut

```
DEFINITION MODULE RealInOut;
(*
   Terminal input/output of REAL values

   The implementation of this module uses the procedures 'ReadString'
   and 'WriteString' of module 'InOut' for reading and writing of REAL values.
   Therefore, redirection of i/o through 'InOut' applies, too.

   From the book 'Programming in Modula-2' by Prof. N. Wirth.
*)

EXPORT QUALIFIED
   ReadReal, WriteReal, WriteRealOct, Done;

VAR Done: BOOLEAN;

PROCEDURE ReadReal (VAR x: REAL);
(*
   - Read a REAL from the terminal.

     out:    x       the number read.

     The range of representable valid real numbers is:
        1.0E-307 <= ABS(r) < 1.0E308

     The syntax accepted for input is:

        realnumber       = fixedpointnumber [exponent].
        fixedpointnumber = [sign] {digit} [ '.' {digit} ].
        exponent         =  ('e' | 'E') [sign] digit {digit}.
        sign             = '+' | '-'.
        digit            = '0'|'1'|'2'|'3'|'4'|'5'|'6'|'7'|'8'|'9'.

     The following numbers are legal representations of one hundred:
     100, 10E1, 100E0, 1000E-1, E2, +E2, 1E2, +1E2, +1E+2, 1E+2 .

     At most 15 digits are significant, leading zeros not counting.
     Input terminates a control character or space.
     DEL or BS is used for backspacing

     The variable 'Done' indicates whether a valid number was read.
*)

PROCEDURE WriteReal (x: REAL; n: CARDINAL);
(*
   - Write a REAL to the terminal, right-justified.

     in:     x       number to write,
             n       minimum field width.

     If fewer than n characters are needed to represent x, leading blanks are output.
     At least 10 characters are needed to write any REAL number.
*)
```

```
PROCEDURE WriteRealOct (x: REAL);
(*
   - Write a REAL to terminal, as four words in octal form

     in:     x       number to write,
*)

END RealInOut.
```

RS232Code

```
DEFINITION MODULE RS232Code;
(*
   High-speed interrupt-driven input/output via the
   RS-232 asynchronous serial port

   This module provides interrupt-driven I/O via the serial port, but the
   Interrupt Service Routine is implemented using in-line code
   (as opposed to IOTRANSFER).  Charcters received are stored in
   a buffer of 100H characters.

   This approach is NOT portable to other Modula-2 implementations,
   but it allows for treatment of interrupts with a high frequency.

   Derived from the Lilith Modula-2 system developed by the group of Prof. N. Wirth
   at ETH Zurich, Switzerland.
*)

EXPORT QUALIFIED
   Init, StartReading, StopReading,
   BusyRead, Read, Write;

PROCEDURE Init (baudRate   : CARDINAL;
                stopBits   : CARDINAL;
                parityBit  : BOOLEAN;
                evenParity : BOOLEAN;
                nbrOfBits  : CARDINAL;
                VAR result : BOOLEAN);
(*
   - Initialize the serial port.

     in:   baudRate    transmission speed,
           stopBits    number of stop bits (usually 1 or 2),
           parityBit   if TRUE, parity is used, otherwise not,
           evenParity  if parity is used, this indicates even/odd,
           nbrOfBits   number of data bits (usually 7 or 8),

     out:  result      TRUE if the initialization was completed.

     The legal values for the parameters depend on the implementation
     (e.g. the range of supported baud rates).
*)

PROCEDURE StartReading;
(*
   - Allow characters to be received from the serial port.

     This procedure initializes the communication controller to generate interrupts
upon reception of a character.  It also unmasks the corresponding interrupt level in
the interrupt controller.
*)
```

```
PROCEDURE StopReading;
(*
  - Disable receiving from the serial port.

    A call to this procedure disables the communication controller
    from generating interrupts.  In addition it terminates the coroutine which
    listens to the line.  The old interrupt vector as well as the old state
    of the interrupt controller (mask) is restored.
*)

PROCEDURE BusyRead (VAR ch       : CHAR;
                    VAR received : BOOLEAN);
(*
  - Read a character from serial port, if one has been received.

    out:  ch              the character received, if any,
          received        TRUE if a character was received.

    If no character has been received, then ch = 0C, and received = FALSE.
*)

PROCEDURE Read (VAR ch: CHAR);
(*
  - Read a character from the serial port.

    out:    ch      the character received.

    As opposed to BusyRead, Read waits for a character to arrive.
*)

PROCEDURE Write (ch: CHAR);
(*
  - Write a character to the serial port.

    in:     ch      character to send.

    Note: no interpretation of characters is made.
*)

END RS232Code.
```

RS232Int

```
DEFINITION MODULE RS232Int;
(*
   Interrupt-driven input/output via the RS-232
   asynchronous serial port

   Interrupts are treated with the standard procedure IOTRANSFER.
   Charcters received are stored in a buffer of 400H characters.

   This module initializes the serial port as follows:
        baudRate    = 1200,
        stopBits    = 1,
        parityBit   = FALSE,
        evenParity = don't care,
         nbrOfBits = 8

   Derived from the Lilith Modula-2 system developed by the group of Prof. N. Wirth
   at ETH Zurich, Switzerland.
*)

EXPORT QUALIFIED
   Init, StartReading, StopReading,
   BusyRead, Read, Write;

PROCEDURE Init (baudRate    : CARDINAL;
                stopBits    : CARDINAL;
                parityBit   : BOOLEAN;
                evenParity : BOOLEAN;
                nbrOfBits   : CARDINAL;
                VAR result : BOOLEAN);
(*
   - Initialize the serial port.

     in:   baudRate     transmission speed,
           stopBits     number of stop bits (usually 1 or 2),
           parityBit    if TRUE, parity is used, otherwise not,
           evenParity   if parity is used, this indicates even/odd,
           nbrOfBits    number of data bits (usually 7 or 8),

     out:  result       TRUE if the initialization was completed.

     The legal values for the parameters depend on the implementation
     (e.g. the range of supported baud rates).
*)

PROCEDURE StartReading;
(*
   - Allow characters to be received from the serial port.

     This procedure initializes the communication controller to generate interrupts
     upon reception of a character.  It also unmasks the corresponding
     interrupt level in the interrupt controller.
*)
```

```
PROCEDURE StopReading;
(*
   - Disable receiving from the serial port.

     A call to this procedure disables the communication controller
     from generating interrupts.  In addition it terminates the coroutine
     which listens to the line.  The old interrupt vector as well as the old state of
     the interrupt controller (mask) is restored.
*)

PROCEDURE BusyRead (VAR ch: CHAR; VAR received: BOOLEAN);
(*
   - Read a character from serial port, if one has been received.

     out:  ch              the character received, if any,
           received        TRUE if a character was received.

     If no character has been received, then ch = 0C, and received = FALSE.
*)

PROCEDURE Read (VAR ch: CHAR);
(*
   - Read a character from the serial port.

     out:    ch      the character received.

     As opposed to BusyRead, Read waits for a character to arrive.
*)

PROCEDURE Write (ch: CHAR);
(*
   - Write a character to the serial port.

     in:     ch      character to send.

     Note: no interpretation of characters is made.
*)

END RS232Int.
```

RS232Polling

```
DEFINITION MODULE RS232Polling;
(*
   Polled input/output via the RS-232 asynchronous serial port

   Since this module does not use interrupts, it is the responsibility of the
   programmer to poll (by calling 'Read' or 'BusyRead') frequently enough to ensure
   that no characters are lost.

   Derived from the Lilith Modula-2 system developed by the group of Prof. N. Wirth
   at ETH Zurich, Switzerland.
*)

EXPORT QUALIFIED
   Init, BusyRead, Read, Write;

PROCEDURE Init (baudRate   : CARDINAL;
                stopBits   : CARDINAL;
                parityBit  : BOOLEAN;
                evenParity : BOOLEAN;
                nbrOfBits  : CARDINAL;
                VAR result : BOOLEAN);
(*
   - Initialize the serial port.

     in:   baudRate    transmission speed,
           stopBits    number of stop bits (usually 1 or 2),
           parityBit   if TRUE, parity is used, otherwise not,
           evenParity  if parity is used, this indicates even/odd,
           nbrOfBits   number of data bits (usually 7 or 8),

     out:  result      TRUE if the initialization was completed.

     The legal values for the parameters depend on the implementation
     (e.g. the range of supported baud rates).
*)

PROCEDURE BusyRead (VAR ch: CHAR; VAR received: BOOLEAN);
(*
   - Read a character from serial port, if one has been received.

     out:  ch              the character received, if any,
           received        TRUE if a character was received.

     If no character has been received, then ch = 0C, and received = FALSE.
*)

PROCEDURE Read (VAR ch: CHAR);
(*
   - Read a character from the serial port.

     out:    ch      the character received.

     As opposed to BusyRead, Read waits for a character to arrive.
*)
```

```
PROCEDURE Write (ch: CHAR);
(*
   - Write a character to the serial port.

     in:     ch      character to send.

     Note: no interpretation of characters is made.
*)

END RS232Polling.
```

RTSCoroutine

```
DEFINITION MODULE RTSCoroutine;

FROM SYSTEM IMPORT PROCESS;

EXPORT QUALIFIED addProcess;

VAR
    addProcess : PROCEDURE( PROCESS );

END RTSCoroutine.
```

RTSDevice

```
DEFINITION MODULE RTSDevice;

FROM SYSTEM IMPORT ADDRESS, PROCESS;

EXPORT QUALIFIED
   GetDeviceStatus, SetDeviceStatus,
   GetPrioMask, SetPrioMask,
   SaveInterruptVector, RestoreInterruptVector,
   InstallHandler, UninstallHandler;

PROCEDURE GetDeviceStatus(   deviceNr : CARDINAL;
                          VAR enabled : BOOLEAN);
(*
   - Return the status of a device in the device mask

     in:    deviceNr  number of the device to be checked bitnumber (0..7) of bit
                      for device in interrupt controller 8259 mask

     out:   enabled   TRUE if interrupts from the device are enabled,
                      FALSE otherwise
*)

PROCEDURE SetDeviceStatus(deviceNr : CARDINAL;
                            enable : BOOLEAN);
(*
   - Set the status of a device in the device mask

     in:    deviceNr  number of the device to enable or disable bitnumber (0..7)
                      of bit for device in interrupt controller 8259 mask

            enable    if TRUE, enable interrupts from the device,
                      otherwise disable them

     The mask register of the interrupt controller will be updated according to the
     current priority and the new device mask.
*)

PROCEDURE GetPrioMask( priorityLevel: CARDINAL ): BITSET;
(*
   - Gets the mask used for the priorityLevel ( only low byte significant )
*)

PROCEDURE SetPrioMask( priorityLevel: CARDINAL; mask: BITSET);
(*
   - Sets the used for the priorityLevel ( only low byte used )
*)

PROCEDURE SaveInterruptVector(vectorNr: CARDINAL;
                              VAR vector: ADDRESS);
(*
   - Save the current value of an interrupt vector

     in:    vectorNr    interrupt vector number

     out:   vector      value of current interrupt vector
*)
```

```
PROCEDURE RestoreInterruptVector (vectorNr : CARDINAL;
                                  vector : ADDRESS);
(*
   - Restore the value of an interrupt vector

     in:   vectorNr   interrupt vector number
           vector     value to restore (previously saved with 'SaveInterruptVector')
*)

PROCEDURE InstallHandler( process : PROCESS;
                          vectorNr : CARDINAL);
(*
   - Install an interrupt handler permanently

     in:   process    process associated with the interrupt handler
           vectorNr   interrupt vector number

     The process is associated permanently to the given interrupt vector number.
     This improves the performance of IOTRANSFER and of the implicit coroutine
     transfer that takes place when the interrupt occurs.  A process may be
     associated to at most one interrupt, and at most one process may be associated
     to the same interrupt.

     'InstallHandler' must only be called after the process has been created
     (by means of NEWPROCESS) and before the process has called IOTRANSFER.
     For instance, it may be called right at the beginning of the code of the
     process.  Except for the call to 'InstallHandler', the code of a permanently
     installed interrupt handler is identical to the code of a regular interrupt
     handler.
*)

PROCEDURE UninstallHandler(process: PROCESS);
(*
   - Uninstall an interrupt handler which has been installed permanently

     in:   process    process associated with the interrupt handler

     In general, there is no need to call this procedure.  The LOGITECH MODULA-2 run-
     time support automatically uninstalls interrupt handlers upon termination
     of a (sub-)program.
*)

END RTSDevice.
```

RTSIntPROC

```
DEFINITION MODULE RTSIntPROC;

(*
   Constraints and Limitations:

   NOTE : Each interrupt PROC must be removed before a new one
          is installed within the save vector !!

          The interrupt PROC must not be in a priority module !!
          nor call a priority module procedure.

          The PROC is executed interrupt off, so it must be as short as possible.

   IMPLEMENTATION :

   All registers are saved; thus the Modula-2 code can be executed without
   taking care of this.
   The End of Interrupt is also sent to the Interrupt Controller before the
   entry of the Modula-2 interrupt procedure.

   Sets a PROC as interrupt service routine, all registers are preserved except the
   stack, that remains the stack of the interrupted process.

   NOTE: this interrupt PROC MUST BE as short as possible, and use as little stack
         as possible.   So will it be fast and reliable.
*)

PROCEDURE SetIntPROC( p: PROC; vector: CARDINAL);

(*
   Removes the interrupt PROC previously installed and restores the old value of the
   interrupt vector.
*)

PROCEDURE RemoveIntPROC(vector: CARDINAL);

(*
   Removes all interrupt PROC installed prevously
*)

PROCEDURE FreeIntPROC;

END RTSIntPROC.
```

RTSM87

```
DEFINITION MODULE RTSM87;

EXPORT QUALIFIED co87Present;

VAR
    co87Present : BOOLEAN;

END RTSM87.
```

RTSMain

```
(*$A+*)

DEFINITION MODULE RTSMain;

FROM SYSTEM IMPORT ADDRESS, BYTE, PROCESS;

EXPORT QUALIFIED
    Status, GetMessage,
    ProcPtr, ProcDescriptor, freeList,
    OverlayKey, OverlayName, OverlayPtr, OverlayDescriptor, overlayList,
    RegisterBlock, ProcessDescriptor, ProcedureKind, ActivationBlock,
    PSPAddress, blockList,
    Process, ProcessPtr, curProcess, activProcess, errorCode,
    Terminate, InstallTermProc, CallTermProc, InstallInitProc, CallInitProc,
    RTDProc, DebuggerRecord, debuggerRecord, Execute,
    overlayInitProc, overlayTermProc;

(* Type definition above shall imperatively correspond to the structures *)
(* defined in RTS.INC                                                    *)

CONST
    CheckValue   = 0FA50H;

(* ***** Errors ***** *)

TYPE
    Status = ( Normal, Warning, Stopped, Fatal,
               Halt, CaseErr, StackOvf, HeapOvf,
               FunctionErr, AdressOverflow, RealOverflow, RealUnderflow,
               BadOperand, CardinalOverflow, IntegerOverflow, RangeErr,
               DivideByZero, CoroutineEnd, CorruptedData, FileStructureErr,
               IllegalInstr, IllErrorCode, TooManyInterrupts, TermListFull,
               InitListFull, NoCoprocessor87 );

TYPE
    Process      = POINTER TO ProcessDescriptor;
    ProcessPtr   = POINTER TO Process;

VAR
    curProcess   : ProcessPtr;   (* always points to activProcess   *)
    activProcess : Process;      (* points to the ProcessDescriptor *)
                                 (* of the active PROCESS           *)

(* ***** Internal informations ***** *)

VAR
    PSPAddress : ADDRESS;
    blockList  : ADDRESS;

PROCEDURE GetMessage(status: Status; VAR message: ARRAY OF CHAR);

(* ***** Termination procedures ***** *)
```

```
TYPE
  ProcPtr        = POINTER TO ProcDescriptor;
  ProcDescriptor = RECORD
                     next     : ProcPtr;
                     termProc : PROC;
                   END;
VAR
  freeList: ProcPtr;

PROCEDURE InstallTermProc( p : PROC );

PROCEDURE CallTermProc;

PROCEDURE InstallInitProc( p : PROC );

PROCEDURE CallInitProc;

(* ***** Overlays and drivers ***** *)

TYPE
  OverlayName       = ARRAY [0..39] OF CHAR;
  OverlayKey        = ARRAY [0.. 2] OF CARDINAL;

  OverlayPtr        = POINTER TO OverlayDescriptor;
  OverlayDescriptor = RECORD
                        overlayKey  : OverlayKey;
                        overlayName : OverlayName;

                        checkWord   : CARDINAL;

                        memoryAddr  : ADDRESS;
                        memorySize  : CARDINAL; (* in paragraphs *)
                        codeSegment : CARDINAL;

                        programLevel: CARDINAL;
                        termProc    : ProcPtr;
                        initProc    : ProcPtr;
                        freeList    : ProcPtr;

                        next        ,
                        prev        : OverlayPtr;

                        CASE overlay : CARDINAL OF
                          0    :     notUsed      : ARRAY [0..14] OF CARDINAL;
                        | 1,2  :     loaderProcess: Process;

                                     priorityMask : CARDINAL;

                                     SP, SS, BP   : CARDINAL;
                                     overlayStatus: Status;

                                     father       ,
                                     parent       : OverlayPtr;
                                     processList  : Process;
                                     resource     : ADDRESS;
                        END;
                        layer      : ADDRESS;
                        dummy      : ARRAY [1..7] OF ADDRESS;
                      END(* OverlayDescriptor*);
```

```
VAR
  overlayList    : OverlayPtr;

(* ***** Overlay Interface procedures ***** *)

VAR
    overlayInitProc : PROC;
    overlayTermProc : PROC;

(* ***** Process descriptor ***** *)

TYPE
    RegisterBlock      = RECORD
                           ES    : CARDINAL;
                           DS    : CARDINAL;
                           DI    : CARDINAL;
                           SI    : CARDINAL;
                           BP    : CARDINAL;
                           dummy : CARDINAL;
                           BX    : CARDINAL;
                           DX    : CARDINAL;
                           CX    : CARDINAL;
                           AX    : CARDINAL;
                           IP    : CARDINAL;
                           CS    : CARDINAL;
                           flag  : CARDINAL;
                         END;

    ProcedureKind      = (FarProcedure, NearProcedure, NestedProcedure);
    ActivationBlock    = RECORD
                           dynamicLink: ADDRESS;
                           IP         : CARDINAL;

                           CASE ProcedureKind OF
                             NearProcedure:
                           | FarProcedure:
                               CS: CARDINAL;
                           | NestedProcedure:
                               staticLink: ADDRESS
                           END;
                         END;

    ProcessDescriptor = RECORD
                           topStack      : POINTER TO RegisterBlock;
                           progStatus    : Status;  (* alignement mandatory *)
                           priorityMask  : BITSET;
                           programLevel  : CARDINAL;
                           heapDesc      : ADDRESS;
                           unused        : ADDRESS;
                           checkWord     : CARDINAL;
                           bottomStack   : CARDINAL;   (* still used ??? *)
                           currOverlay   : OverlayPtr;
                           interruptDesc : CARDINAL;
                           processList   : Process;
                           dummy         : ARRAY [1..3] OF ADDRESS;
                         END;

(* ***** Debugger interface ***** *)
```

```
TYPE
    RTDProc        = PROCEDURE(PROCESS, ADDRESS);
                       (* active process and overlay list *)

    DebuggerRecord = RECORD
                       (* The debugger ID is initialized with the CheckValue *)
                       (* The RTD initialize it to 0                         *)
                       debuggerId     : CARDINAL;
                       beforeInitCode : RTDProc;
                       beforeMainCode : RTDProc;
                       beforeTermProc : RTDProc;
                       beforeExit     : RTDProc;
                     END;

VAR
    debuggerRecord : DebuggerRecord;

(* ***** Program termination ***** *)

VAR
    errorCode : BYTE;

PROCEDURE Terminate( st : Status );

PROCEDURE Execute;
(* Warning : upon entry, ES:DI is a pointer to the address of the code *)
(*           to execute !!!                                            *)

END RTSMain.
```

SimpleTerm

```
DEFINITION MODULE SimpleTerm;

(* All the procedures above use the standard console device from MS-DOS  *)
(* and thus can be redirected as DOS allows it                           *)

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

PROCEDURE WriteString( s : ARRAY OF CHAR );
(* Displays the string s on DOS standard output *)

PROCEDURE WriteLn;
(* Displays an end of line on DOS standard output *)

PROCEDURE Write( ch: CHAR );
(* Displays the character ch on DOS standard output *)

PROCEDURE Read( VAR ch: CHAR );
(* Reads a character from DOS standard input *)

PROCEDURE KeyPressed(): BOOLEAN;
(* Tests if any character is ready from DOS standard input *)

PROCEDURE ReadString( VAR s: ARRAY OF CHAR );
(* Gets a string from DOS standard input : ESC or RETURN ends the input *)

PROCEDURE ReadAgain;

END SimpleTerm.
```

Sounds

```
DEFINITION MODULE Sounds;

EXPORT QUALIFIED
   Sound, NoSound;

PROCEDURE Sound(hertz: INTEGER);
(*
  Accesses the PC speaker with the frequency of hertz Hertz.

  The specified frequency will be emitted until you call the procedure NoSound.
  Frequencies between 21 and 32767 Hertz can be produced.
*)

PROCEDURE NoSound;
(*
  Turns off the PC speaker.
*)

END Sounds.
```

Storage

```
DEFINITION MODULE Storage;
(*
   Standard dynamic storage management

   Storage management for dynamic variables.  Calls to the Modula-2 standard
   procedures NEW and DISPOSE are translated into calls to ALLOCATE and DEALLOCATE.
   The standard way to provide these two procedures is to import them from
   this module 'Storage'.
*)

FROM SYSTEM IMPORT ADDRESS;

EXPORT QUALIFIED
   ALLOCATE, DEALLOCATE, Available,
   InstallHeap, RemoveHeap;

PROCEDURE ALLOCATE (VAR a: ADDRESS; size: CARDINAL);
(*
   - Allocate some dynamic storage (contiguous memory area).

     in:     size    number of bytes to allocate,

     out:    a       ADDRESS of allocated storage.

     The actual number of bytes allocated may be slightly greater
     than 'size', due to administrative overhead.

     Errors: If not enough space is available, or when attempting
     to allocate more than 65520 (0FFF0H) bytes at once, then the calling program is
     terminated with the status 'heapovf'.
*)

PROCEDURE DEALLOCATE (VAR a: ADDRESS; size: CARDINAL);
(*
   - Release some dynamic storage (contiguous memory area).

     in:     a       ADDRESS of the area to release,
             size    number of bytes to be released,

     out:    a       set to NIL.

     The storage area released is made available for subsequent calls to ALLOCATE.
*)

PROCEDURE Available (size: CARDINAL) : BOOLEAN;
(*
   - Test whether some number of bytes could be allocated.

     in:     size    number of bytes

     out:    TRUE if ALLOCATE (p, size) would succeed.
*)
```

```
PROCEDURE InstallHeap;
(*
   - Used internally by the loader
*)

PROCEDURE RemoveHeap;
(*
   - Used internally by the loader
*)

END Storage.
```

Strings

```
DEFINITION MODULE Strings;
(*
   Variable-length character strings handler.

   NOTE: For most of these string handling procedures,there is the possibility of the
   user not providing a variable large enough to contain the result of a string
   operation.  Should this possibility arise, truncation may result, as there will be
   no other error notification.  The implementation of this module does not cause a
   range error, instead, it truncates silently.

   String variables have the following characteristics:
   - They are of type ARRAY OF CHAR.
   - The array lower bound must be zero.
   - The length of the string is the size of the string variable,
     unless a null character (0C) occurs in the string to indicate end of string.
*)

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

PROCEDURE Assign (VAR source, dest: ARRAY OF CHAR);
(*
   - Assign the contents of string variable source into string variable dest

     in:     source

     out:    dest
*)

PROCEDURE Insert (substr  : ARRAY OF CHAR;
                  VAR str : ARRAY OF CHAR;
                  inx     : CARDINAL);
(*
   - Insert the string substr into str,starting at str[inx].

     in:     substr
             str
             inx

     out:    str

     If inx is equal or greater than Length(str)
     then substr is appended to end of dest.
*)
```

```
PROCEDURE Delete (VAR str : ARRAY OF CHAR;
                  inx     : CARDINAL;
                  len     : CARDINAL);
(*
   - Delete len characters from str, starting at str[inx].

     in:     str
             inx
             len

     out:    str

     If inx >= Length(str) then nothing happens.  If there are
     not len characters to delete, characters to the end of string are deleted.
*)

PROCEDURE Pos (substr, str: ARRAY OF CHAR): CARDINAL;
(*
   - Return the index into str of the first occurrence of the substr.

     in:     substr
             str

Pos returns a value greater then HIGH(str) if no
occurrence of the substring is found
*)

PROCEDURE  Copy (str        : ARRAY OF CHAR;
                 inx        : CARDINAL;
                 len        : CARDINAL;
                 VAR result : ARRAY OF CHAR);
(*
   - Copy at most len characters from str into result.

     in:     str     source string,
             inx     starting position in 'str',
             len     maximum number of characters to copy,

     out:    result  copied string
*)

PROCEDURE Concat (s1, s2     : ARRAY OF CHAR;
                  VAR result : ARRAY OF CHAR);
(*
   - Concatenate two strings.

     in:     s1      left string,
             s2      right string,

     out:    result  receives left string followed by right string.
*)

PROCEDURE Length (VAR str: ARRAY OF CHAR): CARDINAL;
(*
   - Return the number of characters in a string.

     in:     str
*)
```

```
PROCEDURE CompareStr (s1, s2: ARRAY OF CHAR): INTEGER;
(*
   - Compare two strings.

     in:     s1
             s2

     Returns an integer value indicating the comparison result:
         -1 if s1 is less than s2;
          0 if s1 equals s2;
          1 if s1 is greater than s2
*)

END Strings.
```

Termbase

```
DEFINITION MODULE Termbase;
(*
   Terminal input/output with redirection hooks
   [Private module of the MODULA-2/86 system]

   Derived from the Lilith Modula-2 system developed by the group of Prof. N. Wirth
   at ETH Zurich, Switzerland.
*)

EXPORT QUALIFIED
   ReadProcedure, StatusProcedure, WriteProcedure,
   AssignRead, AssignWrite, UnAssignRead, UnAssignWrite,
   Read, KeyPressed, Write;

TYPE
   ReadProcedure = PROCEDURE (VAR CHAR);
   (*
     - To assign a private read procedure (for redirection of input)
       a procedure of type 'ReadProcedure' must be provided.
       This procedure returns a character from the input device.
       It waits until a character hes been entered.
   *)

TYPE
   StatusProcedure = PROCEDURE (): BOOLEAN;
   (*
     - To assign a private status-procedure (for redirection of input)
       a procedure of type 'StatusProcedure' must be provided.
       This procedure returns TRUE, if a character is available to read,
       FALSE otherwise.
   *)

TYPE
   WriteProcedure = PROCEDURE (CHAR);
   (*
     - To assign a private write procedure (for redirection of output)
       a procedure of type 'WriteProcedure' must be provided.  This is typically
       used to redirect output to a file or to the screen and a file (log file).
       Special interpretation of characters sent to the screen can be performed
       in such a private driver procedure.
   *)
```

```
PROCEDURE AssignRead (rp: ReadProcedure;
                      sp: StatusProcedure;
                       VAR done: BOOLEAN);
(*
   - Install read and status routines for terminal input.

     in:   rp    read-a-character procedure,
           sp    is-character-available function,

     out:  done  TRUE if the installation was done.

     Initially the corresponding procedures of 'Keyboard' are installed.

     Subsequent assignments will be valid until the next 'UnAssignRead' is executed
     or until the (sub-)program which has installed the procedures terminates.  Upon
     termination of a program, the read and status procedures allocated by that
     program are removed.  Read procedures are non-sharable resources
     (see module 'Program').

     The assignments are implemented in a stack manner.  When a read procedure is
     removed, the previously valid procedure becomes valid again.  Up to six levels
     of re-assignment are allowed.  Done = FALSE if this depth is exceeded.  During
     execution of a read or status procedure, this assignments-stack is decremented,
     which allows an installed routine to call recursively Terminal.Read and/or
     Terminal.KeyPressed to activate the previously installed routine.  At the lowest
     level however, the stack is not decremented.
*)

PROCEDURE AssignWrite (wp: WriteProcedure;
                       VAR done: BOOLEAN);
(*
   - Install write routine for terminal output.

     in:   wp    character output procedure,

     out:  done  set TRUE if the installation was done.

     [See AssignRead above.]
     Initially the procedure Display.Write is assigned.
*)

PROCEDURE UnAssignRead (VAR done: BOOLEAN);
(*
   - Undo the last AssignRead by the current program.

     out:  done  set TRUE if there was something to unassign.

     The previously valid procedures become active again.
*)

PROCEDURE UnAssignWrite (VAR done: BOOLEAN);
(*
   - Undo the last AssignWrite by the current program.

     out:  done  set TRUE if there was something to unassign.

     The previously valid procedure becomes active again.
*)
```

```
PROCEDURE Read (VAR ch: CHAR);
(*
   - Read a character using the current input procedure.

     out:  ch    the character read.

     Uses the current read-procedure, as assigned by AssignRead.
*)

PROCEDURE KeyPressed (): BOOLEAN;
(*
   - Test if a character is available from the current input.

     Uses the current status-procedure, as assigned by AssignRead.
*)

PROCEDURE Write (ch: CHAR);
(*
   - Write a character to the current output.

     in:   ch    character to write.

     Uses the current write-procedure as assigned by AssignWrite.
*)

END Termbase.
```

Terminal

```
DEFINITION MODULE Terminal;
(*

   Terminal Input/Output

   This module uses the read and write procedures from module
   TermBase, which allows to redirect the i/o.

   Derived from the Lilith Modula-2 system developed by the group of Prof. N. Wirth
   at ETH Zurich, Switzerland.
*)

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

PROCEDURE Read (VAR ch: CHAR);
(*
   - Read a character from the terminal.

     out:    ch      character that was read.

     The character is not echoed.
     The character ASCII.cr is transformed into ASCII.EOL.
*)

PROCEDURE KeyPressed (): BOOLEAN;
(*
   - Test if a character is available to Read from terminal.
*)

PROCEDURE ReadAgain;
(*
   - Undo the last read: Make the last character be re-read.
*)

PROCEDURE ReadString(VAR string: ARRAY OF CHAR);
(*
   - Read (with echo) a line from the terminal.

     out:    string  receives the text of the line

     Characters are accepted (and echoed) from the keyboard until <cr> is entered.
     The <cr> is not returned or echoed.  <del> and <bs> can be used for editing.
     Tabs may be entered, but are expanded into blanks immediately.
     No other control characters may be entered.
*)
```

```
PROCEDURE Write (ch: CHAR);
(*
   - Write a character to the terminal.

     in:     ch      character to be written.

     If terminal output has not been redirected,
     the following interpretations are made:

       ASCII.EOL  (36C) = go to beginning of next line
       ASCII.ff   (14C) = clear screen and set cursor home
       ASCII.del (177C) = erase the last character on the left
       ASCII.bs   (10C) = move 1 character to the left
       ASCII.cr   (15C) = go to beginning of current line
       ASCII.lf   (12C) = move 1 line down, same column
*)

PROCEDURE WriteString (string: ARRAY OF CHAR);
(*
   - Write a string to the terminal.

     in:     string          string to be written.

     The string is terminated by its physical length or by a null character (0C).
*)

PROCEDURE WriteLn;
(*
   - Write a new-line to the terminal.
     [Equivalent to Write(ASCII.EOL)]
*)

END Terminal.
```

TimeDate

```
DEFINITION MODULE TimeDate;
(*
   Access to the system's date and time
*)

EXPORT QUALIFIED
   Time,
   SetTime, GetTime,
   CompareTime, TimeToZero,
   TimeToString;

TYPE
   Time = RECORD day, minute, millisec: CARDINAL; END;
   (*
     - date and time of day

       'day' is    : Bits 0..4 = day of month (1..31),
                     Bits 5..8 = month of the year (1..12),
                     Bits 9..15 = year - 1900.
       'minute'    : is hour * 60 + minutes.
       'millisec'  : is second * 1000 + milliseconds,
                     starting with 0 at every minute.
   *)

PROCEDURE GetTime (VAR curTime: Time);
(*
   - Return the current date and time.

     out:    curTime         record containing date and time.

     On systems which do not keep date or time, 'GetTime'
     returns a pseudo-random number.
*)

PROCEDURE SetTime (curTime: Time);
(*
   - Set the current date and time.

     in:     curTime         record containing date and time.

     On systems which do not keep date or time, this call has no effect.
*)

PROCEDURE CompareTime(t1, t2: Time): INTEGER;
(*
   - compare two dates and time

     in :   t1, t2 two time structures to compare
     out:   return integer value indicating result of comparison
             -1  t1 < t2
              0  t1 = t2
             +1  t1 > t2
*)
```

```
PROCEDURE TimeToZero(VAR t: Time);
(*
   - initialize time and date to zero

     out:    t   zero time  00-00-00 00:00:00
*)

PROCEDURE TimeToString(t: Time; VAR s: ARRAY OF CHAR);
(*
   - convert time into a string

     in :    t   time structure to be convert to a string
     out:    s   string containing description of date and time given in t.

     The length of s should be at least 17 characters and the time will be of format:
        yy-mm-dd hh:nn:ss

     where
        yy is year (last 2 digits only)
        mm is month (1..12)
        dd is day of month (1..31)
        hh is hours (0..23)
        nn is minutes (0..59)
        ss is seconds (0..59)
*)

END TimeDate.
```

Notes:

9.3 Library Cross Reference

The following procedures with referenced modules are in alphabetical order — first, by procedures whose names begin in upper case – then, by those in lower case.

Procedure	Module
ADDRESS	SYSTEM
ADR	SYSTEM
ALLOCATE	Storage
AX	SYSTEM
ActivationBlock	RTSMain
AddDec	Decimals
Again	FileSystem
Alloc	DynMem
Arc	Graphics
Assign	Strings
AssignRead	Termbase
AssignWrite	Termbase
Avail	DynMem
Available	Storage
Awaited	Processes
BASE	NumberConversion
BP	SYSTEM
BX	SYSTEM
BYTE	SYSTEM
BackgroundColor	Graphics
BackgroundPattern	Graphics

Procedure	Module
Black	Graphics
Blue	Graphics
Brown	Graphics
BusyRead	RS232Code
BusyRead	RS232Int
BusyRead	RS232Polling
Button	Mouse
ButtonSet	Mouse
CODE	SYSTEM
CR	LogiFile
CS	SYSTEM
CURSORSHAPE	Graphics
CURSORSHAPEPOIN	Graphics
CX	SYSTEM
CallInitProc	RTSMain
CallOverlay	Overlay
CallOverlayInLayer	Overlay
CallTermProc	RTSMain
CancelRedirection	DOS31
CardToString	NumberConversion
ChangeDirectory	DiskDirect
Circle	Graphics
Clear	DurationOps
ClearWindow	Graphics
ClipDot	Graphics
ClipLine	Graphics
Close	FileSystem
Close	LogiFile
CloseInput	InOut
CloseOutput	InOut

Procedure	Module
ColorTable	Graphics
Command	FileSystem
CompareDec	Decimals
CompareStr	Strings
CompareTime	TimeDate
Concat	Strings
ConditionalOff	Mouse
ConvertCardinal	Conversions
ConvertHex	Conversions
ConvertInteger	Conversions
ConvertLongInt	Conversions
ConvertOctal	Conversions
Copy	Strings
Create	FileSystem
Create	LogiFile
CreateMedium	FileSystem
CreateNewFile	DOS3
CreateTemporary	DOS3
CurrentDirectory	DiskDirectory
CurrentDrive	DiskDirectory
CursorColor	Graphics
CursorShape	Graphics
CursorShow	Graphics
CursorVisible	Graphics
CursorWrap	Graphics
Cyan	Graphics

Procedure	Module
DEALLOCATE	Storage
DECIMAL	Decimals
DI	SYSTEM
DOSAlloc	DOSMemory
DOSAvail	DOSMemory
DOSCALL	SYSTEM
DOSDeAlloc	DOSMemory
DOSGetMaxSize	DOSMemory
DOSSetSize	DOSMemory
DS	SYSTEM
DX	SYSTEM
DarkGray	Graphics
Date	Calendar
DeAlloc	DynMem
DeInstallOverlay	Overlay
DecCur	Decimals
DecDigits	Decimals
DecPoint	Decimals
DecRepr	Decimals
DecSep	Decimals
DecState	Decimals
DecStatus	Decimals
DecToStr	Decimals
DecValid	Decimals
Delay	Delay
Delete	Directories
Delete	FileSystem
Delete	LogiFile
Delete	Strings
DeltaDate	Calendar

Procedure	Module
Diff	DurationOps
DirQuery	Directories
DirQueryProc	Directories
DirResult	Directories
DirectoryProc	FileSystem
DisableBreak	Break
DiskDirProc	DiskFiles
DiskFileProc	DiskFiles
DisplayCursor	Graphics
DisposeLayer	Overlay
DivDec	Decimals
DoIo	FileSystem
Done	InOut
Done	RealInOut
DosCommand	Exec
DosShell	Exec
Dot	Graphics
DriverInstalled	Mouse
Duration	DurationOps
EOF	LogiFile
EOL	ASCII
EOL	InOut
EOL	LogiFile
ES	SYSTEM
EmptyUnitSet	DurationOps
EnableBreak	Break
EndFile	LogiFile
Equal	DurationOps
EraseCursor	Graphics

Procedure	Module
ErrorCode	Overlay
Event	Mouse
EventHandler	Mouse
EventSet	Mouse
Execute	Exec
Execute	RTSMain
ExitToOS	ErrorCode
FNPartSet	FileNames
FNParts	FileNames
File	FileSystem
File	LogiFile
FileNameAndOptions	Options
FileNameChar	FileSystem
FileProc	FileSystem
FillRect	Graphics
Flag	FileSystem
FlagReset	Mouse
FlagSet	FileSystem
Float	FloatingUtilities
FloodFill	Graphics
ForegroundColor	Graphics
Format	DurationOp
FormatOf	DurationOp
Frac	FloatingUtilities

Procedure	Module
GETREG	SYSTEM
GetButPres	Mouse
GetButRel	Mouse
GetCursorPosition	Graphics
GetDeviceStatus	Devices
GetDeviceStatus	RTSDevice
GetDotColor	Graphics
GetErrorCode	ErrorCode
GetErrorCode	Overlay
GetExtendedError	DOS3
GetFileDate	LogiFile
GetMachineName	DOS31
GetMessage	RTSMain
GetOption	Options
GetPos	FileSystem
GetPos	LogiFile
GetPosBut	Mouse
GetPrinterSetup	DOS31
GetProgramSegmentPrefix	DOS3
GetRedirectionListEntry	DOS31
GetScreenExt	Graphics
GetScreenMode	Graphics
GetTime	TimeDate
GetWindow	Graphics
GraphicCursor	Mouse
Greater	DurationOps
GreaterOrEqual	DurationOps
Green	Graphics
HideCursor	Mouse

Procedure	Module
INBYTE	SYSTEM
IOTRANSFER	SYSTEM
Init	Processes
Init	RS232Code
Init	RS232Int
Init	RS232Polling
InitDiskSystem	DiskFiles
Insert	Strings
InstallBreak	Break
InstallDynMem	DynMem
InstallHandler	Devices
InstallHandler	RTSDevice
InstallHeap	Storage
InstallInitProc	RTSMain
InstallOverlay	Overlay
InstallOverlayInLayer	Overlay
InstallTermProc	RTSMain
Int	FloatingUtilities
IntToString	NumberConversion
KeyPressed	Keyboard
KeyPressed	SimpleTerm
KeyPressed	Termbase
KeyPressed	Terminal
LF	LogiFile
LayerId	Overlay
Length	FileSystem
Length	Strings
LightBlue	Graphics
LightCyan	Graphics

Procedure	Module
LightGray	Graphics
LightGreen	Graphics
LightMagenta	Graphics
LightPenOff	Mouse
LightPenOn	Mouse
LightRed	Graphics
Line	Graphics
LockUnlockFileA	DOS3
LongIntToString	NumberConversion
Lookup	FileSystem
LookupFile	Lookup
Magenta	Graphics
MakeDir	DiskDirectory
MaxBase	NumberConversion
MediumType	FileSystem
ModifyByte	LogiFile
ModifyWord	LogiFile
MoveCursor	Graphics
MulDec	Decimals
NEWPROCESS	SYSTEM
NUL	LogiFile
NamePartSet	Options
NameParts	Options
NegDec	Decimals
NewLayer	Overlay
NoSound	Sounds
NumToString	NumberConversion

Procedure	Module
OUTBYTE	SYSTEM
Open	LogiFile
OpenInput	InOut
OpenMode	LogiFile
OpenOutput	InOut
OverlayDescriptor	RTSMain
OverlayId	Overlay
OverlayKey	RTSMain
OverlayName	RTSMain
OverlayPtr	RTSMain
PROCESS	SYSTEM
PSPAddress	RTSMain
Palette	Graphics
Pattern	Graphics
Pos	Strings
ProcDescriptor	RTSMain
ProcPtr	RTSMain
ProcedureKind	RTSMain
Process	RTSMain
ProcessDescriptor	RTSMain
ProcessPtr	RTSMain
RTDProc	RTSMain
Read	InOut
Read	Keyboard
Read	RS232Code
Read	RS232Int
Read	RS232Polling
Read	SimpleTerm
Read	Termbase
Read	Terminal

Procedure	Module
ReadAgain	SimpleTerm
ReadAgain	Terminal
ReadByte	FileSystem
ReadByte	LogiFile
ReadCard	InOut
ReadCardinal	CardinalIO
ReadChar	FileSystem
ReadChar	LogiFile
ReadFileName	FileNames
ReadHex	CardinalIO
ReadInt	InOut
ReadLongInt	LongIO
ReadMotionCount	Mouse
ReadNBytes	FileSystem
ReadNBytes	LogiFile
ReadProcedure	Termbase
ReadReal	RealInOut
ReadString	InOut
ReadString	SimpleTerm
ReadString	Terminal
ReadWord	FileSystem
ReadWord	LogiFile
ReadWrd	InOut
RealToString	RealConversion
Red	Graphics
RedirectDevice	DOS31
RegisterBlock	RTSMain
Remainder	Decimals
RemoveDir	DiskDirectory
RemoveHeap	Storage
RemoveMedium	FileSystem

Procedure	Module
Rename	Directories
Rename	FileSystem
Reset	FileSystem
Reset	LogiFile
ResetDiskSys	DiskDirectory
ResetDrive	DiskDirectory
Response	FileSystem
RestoreInterrupt	Devices
RestoreInterrupt	RTSDevice
RestorePicture	Graphics
Round	FloatingUtilities
Run	Exec
SEND	Processes
SETREG	SYSTEM
SI	SYSTEM
SIGNAL	Processes
SIZE	SYSTEM
SP	SYSTEM
SWI	SYSTEM
SaveInterruptVector	Devices
SaveInterruptVector	RTSDevice
SavePicture	Graphics
ScreenMode	Graphics
SelectDrive	DiskDirectory
SetCursorPos	Mouse
SetDeviceStatus	Devices
SetDeviceStatus	RTSDevice
SetErrorCode	ErrorCode
SetEventHandler	Mouse
SetGraphicCursor	Mouse
SetHorizontalLimits	Mouse

Procedure	Module
SetMickeysPerPixel	Mouse
SetModify	FileSystem
SetOpen	FileSystem
SetPos	FileSystem
SetPos	LogiFile
SetPrinterSetup	DOS31
SetRead	FileSystem
SetSpeedThreshold	Mouse
SetTextCursor	Mouse
SetTime	TimeDate
SetVerticalLimit	Mouse
SetWrite	FileSystem
ShowCursor	Mouse
Sound	Sounds
StartProcess	Processes
StartReading	RS232Code
StartReading	RS232Int
Status	RTSMain
StatusProcedure	Termbase
StopReading	RS232Code
StopReading	RS232Int
StrToDec	Decimals
StringToCard	NumberConv
StringToInt	NumberConv
StringToLongInt	NumberConv
StringToNum	NumberConv
StringToReal	RealConversions
SubDec	Decimals
Sum	DurationOps

Procedure	Module
TRANSFER	SYSTEM
TSIZE	SYSTEM
Terminate	RTSMain
Termination	Options
Text	Graphics
Time	TimeDate
TimeToDate	Calendar
TimeToString	TimeDate
TimeToZero	TimeDate
Trunc	FloatingUtilities
UnAssignRead	Termbase
UnAssignWrite	Termbase
UnInstallBreak	Break
UninstallHandle	Devices
UninstallHandle	RTSDevice
Unit	DurationOps
UnitSet	DurationOps
WAIT	Processes
WORD	SYSTEM
White	Graphics
Window	Graphics
Write	Display
Write	InOut
Write	RS232Code
Write	RS232Int
Write	RS232Polling
Write	SimpleTerm
Write	Termbase
Write	Terminal

Procedure	Module
WriteByte	FileSystem
WriteByte	LogiFile
WriteCard	InOut
WriteCardinal	CardinalIO
WriteChar	FileSystem
WriteChar	LogiFile
WriteHex	CardinalIO
WriteHex	InOut
WriteInt	InOut
WriteLn	InOut
WriteLn	SimpleTerm
WriteLn	Terminal
WriteLongInt	LongIO
WriteNBytes	FileSystem
WriteNBytes	LogiFile
WriteOct	InOut
WriteProcedure	Termbase
WriteReal	RealInOut
WriteRealOct	RealInOut
WriteResponse	FileMessage
WriteString	InOut
WriteString	SimpleTerm
WriteString	Terminal
WriteWord	FileSystem
WriteWord	LogiFile
WriteWrd	InOut
Yellow	Graphics

Procedure	Module
ack	ASCII
activProcess	RTSMain
addProcess	RTSCoroutine
arctan	MathLib0
bel	ASCII
blockList	RTSMain
bs	ASCII
can	ASCII
co87Present	RTSM87
cos	MathLib0
cr	ASCII
curProcess	RTSMain
cursorHeight	Graphics
cursorWidth	Graphics
dc1	ASCII
dc2	ASCII
dc3	ASCII
dc4	ASCII
debuggerRecord	RTSMain
del	ASCII
dle	ASCII
em	ASCII
enq	ASCII
entier	MathLib0
eot	ASCII

Procedure	Module
errorCode	RTSMain
esc	ASCII
etb	ASCII
etx	ASCII
exp	MathLib0
ff	ASCII
freeList	RTSMain
fs	ASCII
gphCMedRes	Graphics
gphHiRes	Graphics
gphMedRes	Graphics
gs	ASCII
ht	ASCII
in	InOut
lf	ASCII
ln	MathLib0
nak	ASCII
nul	ASCII
out	InOut
overlayInitProc	RTSMain
overlayList	RTSMain
overlayTermProc	RTSMain

Procedure	Module
real	MathLib0
rs	ASCII
si	ASCII
sin	MathLib0
so	ASCII
soh	ASCII
sqrt	MathLib0
stx	ASCII
sub	ASCII
syn	ASCII
termCH	InOut
txtCHiRes	Graphics
txtCMedRes	Graphics
txtHiRes	Graphics
txtMedRes	Graphics
us	ASCII
vt	ASCII

Appendices

Appendix A
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New York, NY 10158

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Modula-2 Users Association (MODUS)
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Palo Alto, CA 94303

Structured Language World
Springer-Verlag New York, Inc.
175 Fifth Avenue
New York, NY 10010

User Groups

Modula-2 Users Associaton (MODUS)
c/o Pacific Systems Group
P.O. Box 51778
Palo Alto, CA 94303

Modula-2 Special Interest Group (SIG)
USUS (USCD Pascal System Users' Society)
P.O. Box 1148
La Jolla, CA 92038

Appendix B
Memory Organization & Run Time Description

B.1 Global Memory Organization

Global memory organization when executing a *LOGITECH Modula-2* program is shown in **Figure B-1**.

After loading a program, run-time support creates the main process which will then execute the program. It then transfers control to this main process.

The memory location of START_MEMORY in Figure B-1 is the address of the first free paragraph after the code and data of a *Modula-2* program. From this address on, chunks of memory can be allocated, through *DOS*, to the application program in order to implement the heap. Such chunks may not be contiguous.

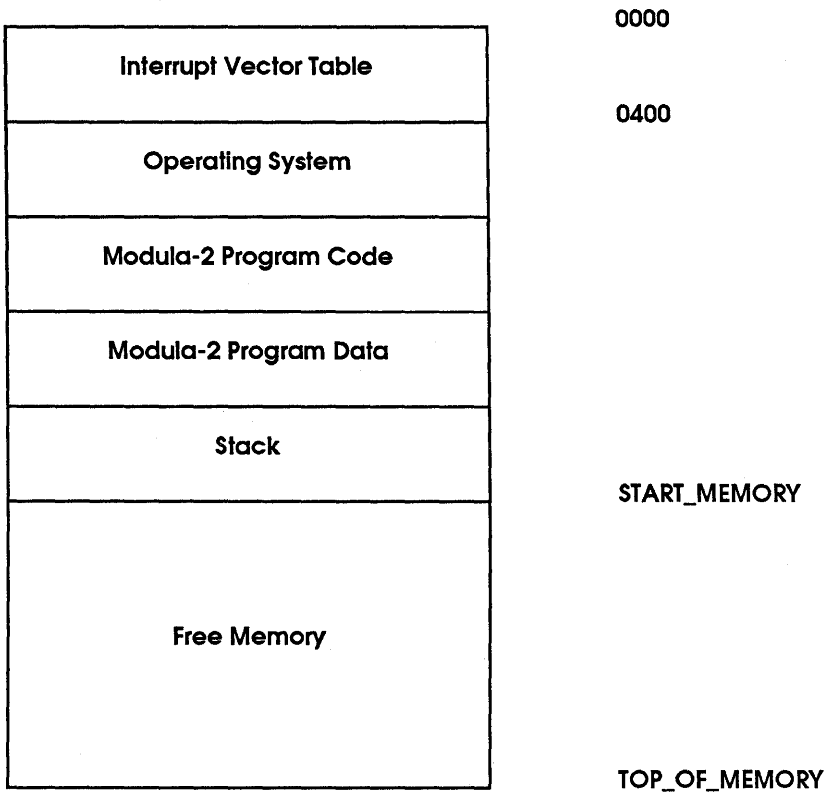


Figure B-1: Global Memory Organization

B.2 Subprograms and Resident Overlays

The following schema is supported by the *LOGITECH Modula-2* Development System only if the ***LOGITECH Linker*** is used to bind the application.

An overlay is a piece of executable code that can be loaded and executed. An overlay can in turn load another overlay on top of itself.

Two different kinds of overlay are supported: *subprogram* overlay and *resident* overlay.

After execution, a subprogram overlay is automatically unloaded from the memory, while a resident overlay gets unloaded from the memory — either upon explicit request, or when the parent overlay subprogram gets loaded. The parent overlay subprogram is the first overlay subprogram found going back in the loading chain. (We will refer to an overlay as "layer" from time to time.)

- The main program is a subprogram overlay; it is also called the **BASE LAYER**.
- A Library module called **Overlay** is the overlay manager. **Overlay** contains procedures that can load and execute subprogram overlays or install and de-install resident overlays.
- The number of layers that can be loaded on top of each other is limited only by the available memory.
- The programmer is not concerned where an overlay is loaded. The overlay manager takes care of finding the place and of loading the new layer.

Figure B-2 shows a possible memory organization when a base layer and two overlays are loaded.

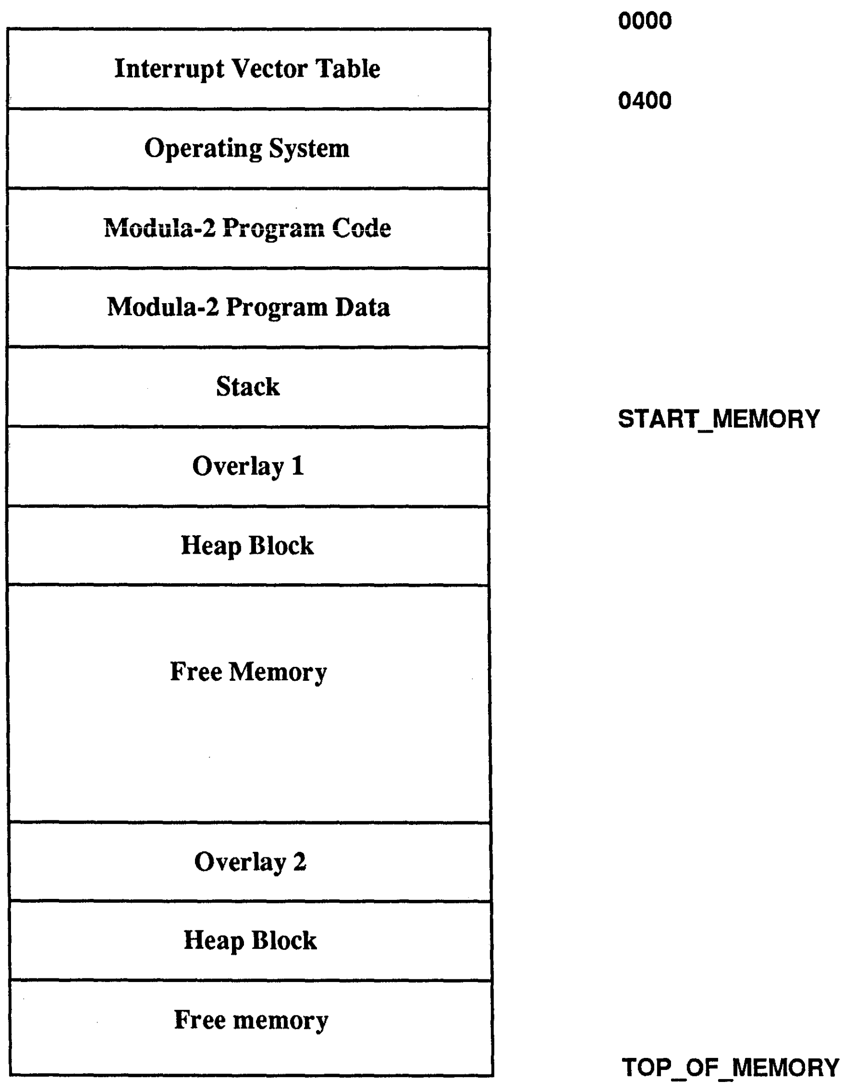
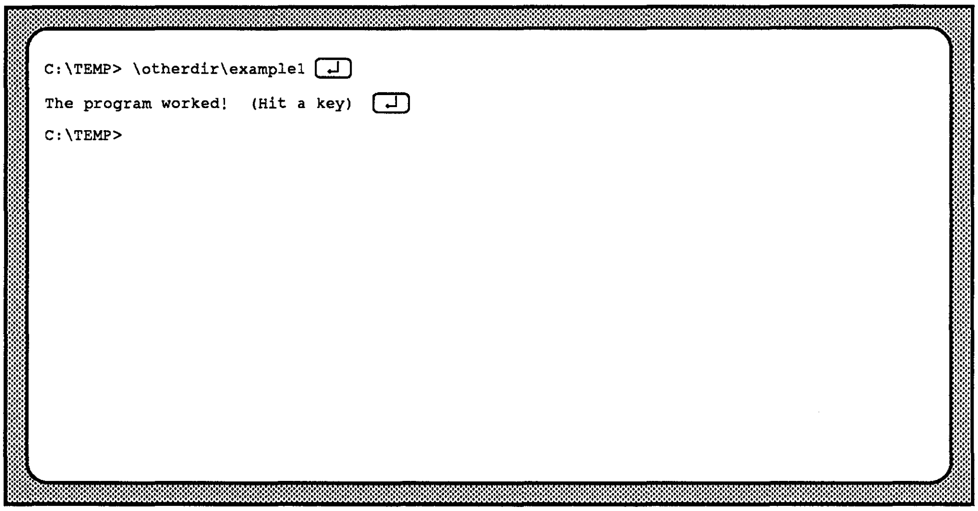


Figure B-2: Memory Organization for Overlays

B.3 Program Execution

To run a ***LOGITECH Modula-2*** program, you enter the name of the program on the DOS command line, concluding it with ↵. The program name can be preceded by a prefix with the drive and\or directory name, in which case the program is loaded from the specified drive or directory.

For example:



```
C:\TEMP> \otherdir\example1 ↵
The program worked!  (Hit a key)  ↵
C:\TEMP>
```

B.4 Processes

When starting a *Modula-2* program, *LOGITECH Modula-2* Run-Time Support automatically creates the main process. This default process gets the stack as its workspace. Figure B-1 and Figure B-2 above, illustrate the organization of the workspace of the main process.

When a new process is created by a call to procedure NEWPROCESS from module SYSTEM, it must be assigned a workspace. This region of memory must be explicitly defined by the programmer. It is usually a variable, owned by the parent process. Such a variable can be global, for example, an ARRAY declared at the level of a module. It can be a dynamic variable, created on the heap by a call to NEW, or it can also be a variable declared local to a procedure, which is allocated on the stack. If a non-global variable is used, make sure the process does not have a longer lifetime than its workspace!

The heap of the process is allocated by *DOS* in *DOS* free memory and is consequently shared by any other process.

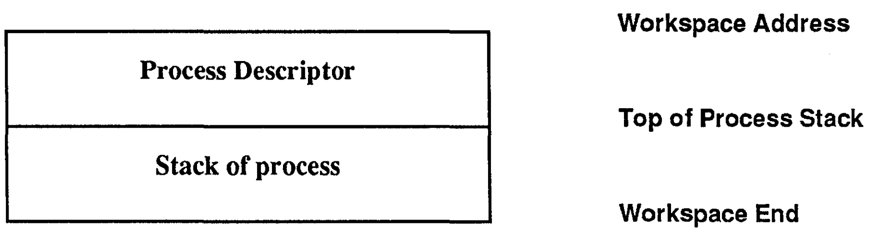


Figure B-3: Process Workspace

The process descriptor of a process created by NEWPROCESS starts at the first paragraph boundary in the workspace of the process. Approximately 200 bytes are needed for the process descriptor plus the initial stack. In addition, at any point in time, there should be approximately 200 bytes of free memory in the workspace of the process. This memory may be needed when an interrupt occurs during the execution of the process, because the standard interrupt handlers of the operating system use the current stack. This is true for any program and is not related in any way to the use of **IOTRANSFER** in ***Modula-2.*** This brings the minimum size of a workspace to approximately 400 bytes, assuming that the corresponding process does nothing at all!

NOTE

If the workspace of the new process is too small, and does not allow a reasonable initialization, the process that calls **NEWPROCESS** will be terminated with a stack overflow.

For any procedure call, some space on the stack is needed. Also, any call to the operating system, needs approximately 100 bytes of stack space. The standard ***LOGITECH Modula-2*** library implements all input and output functions by means of calls to the operating system. Taking everything into account, even the most simple process that does terminal or file I/O, requires a workspace of at least **2K**. For more complicated processes, a larger workspace is required.

The workspace of a process must be large enough to hold its stack. If the process stack grows too much, the program containing this process is aborted with a stack overflow. The maximum size of a process workspace is approximately 64K.

B.5 Allocation of Variables

Local variables are declared inside a procedure. They are allocated with the procedure activation record on the stack of the process that executes the procedure call. The variables of modules which are declared local to a procedure are allocated at the same place. The procedure parameters are also allocated inside the procedure activation record.

Because the procedure activation record only exists while the procedure is being executed, the lifetime of local variables and of procedure parameters is limited to the duration of the procedure call. Every time a procedure is called, a new instance of its activation record is created. If the procedure is recursive, or is called by more than one process at the same time, several instances of its procedure activation record will exist.

Global variables that are declared in modules which are not local to a procedure come into existence when the program or subprogram that contains this module is loaded. Their lifetime is limited by the lifetime of the program or subprogram to which they belong.

There is only one instance of the global variables of a module. Global variables are shared by all procedures and processes of a program. A program that calls a subprogram also shares its global variables with the subprogram.

Variables are allocated in the order of their declaration: the first variable has the lowest address. Alignment of variables depends on the setting of the alignment option. If alignment is on, variables with a size greater than one byte are allocated on even addresses. Byte sized variables can be allocated on odd addresses. Alignment can improve the performance of the program for an ***8086*** based system.

The maximum allowance for all local variables of a procedure is approximately 32K bytes. The same limit exists for the total size of all parameters of a procedure. In practice, however, these sizes are much more limited by the size of the stack, which cannot exceed 64K bytes. The limit for the total size of all global variables declared in one program module or in one implementation module, including those declared in the corresponding definition module, is approximately 64K bytes. The total size of the global variables in all modules of a program is only limited by ***DOS***.

B.6 The Heap

The library module **Storage** implememts the heap management. On each chunk of memory (typically 10 - 40 K) it does its own memory management. This is transparent and you can directly get and release memory by means of **ALLOCATE** and **DEALLOCATE.**

Modula-2 provides the standard procedures **NEW** and **DISPOSE** to allocate and deallocate dynamic memory. The compiler maps calls to these procedures to calls of the procedures **ALLOCATE** and **DEALLOCATE.** When using **NEW** or **DISPOSE** in a module, procedures **ALLOCATE** or **DEALLOCATE** must be imported or declared in that module. The standard way is to import these procedures from the library module **Storage.** However, a program may declare and use its own versions of **ALLOCATE** or **DEALLOCATE.** In this way, a program can implement its own heap management. In general, the strategy for allocation and deallocation of dynamic memory will then differ from the default strategy provided by module **Storage.**

B.7 The Stack

The stack holds different kinds of data:

- Procedure activation records
- Temporary values during the evaluation of an expression
- Other temporary data

Every process owns its private stack which is part of its workspace. Upon creation of a process by a call to **NEWPROCESS** the stack is set such that the first word pushed onto the stack occupies the last word at the highest even address in the workspace. The stack grows from the end of the workspace toward lower addresses.

Maximum stack size is 64K bytes. However, in most applications the workspace needed by a process is less than 64K. Therefore, the stack size is usually limited by the size of the workspace and the occupation of the heap.

The default size of the main process stack is a fixed value (8000 bytes); you can change this at link time by using a different size. Refer to the section on linker options.

B.8 The Procedure Activation Record

Each time there is a procedure call, a new procedure activation record is created on the stack of the current process. Depending on whether *8086/8088* or *80186/80286* code is generated, the activation record format differs slightly. The procedure activation record contains the following information (see also **Figure B-4** and **Figure B-5** below):

Procedure parameters	Are pushed, if they exist, onto the stack in the order they are declared. Because the stack grows toward lower addresses, the last parameter is found at the lowest address.
Static link	A pointer, within the same stack, to another procedure activation record which constitutes the static environment of the procedure. The static link can find variables or parameters in the static environment of the procedure. The static link is only for procedures which are declared nested inside of another procedure. The static environment consists of the parameters and variables which are declared in the embedding procedure(s). When code is generated for *80186/80286*, the static link does not exist, but is implemented as a display.
Return address	If the procedure was activated by a **near** procedure call, the return address is an offset value only, which corresponds to the instruction pointer. If the procedure was activated by a **far** call, there is also a segment value which corresponds to the code segment of the calling procedure.
Dynamic link	Points to the previous procedure activation record within the same stack.
Display (*186/286* only)	A table of pointers, within the same stack, to the other procedure activation records which make up the static environment of the procedure. The number of table entries corresponds to the lexical nesting level of the current procedure. The display table is used to find variables or parameters in the static environment of the procedure. The display is only generated if the code generation option for *80186/80286* was selected. For *8086/8088* code, access to the static environment is implemented by the static link.
Local data	All the variables declared inside the procedure.

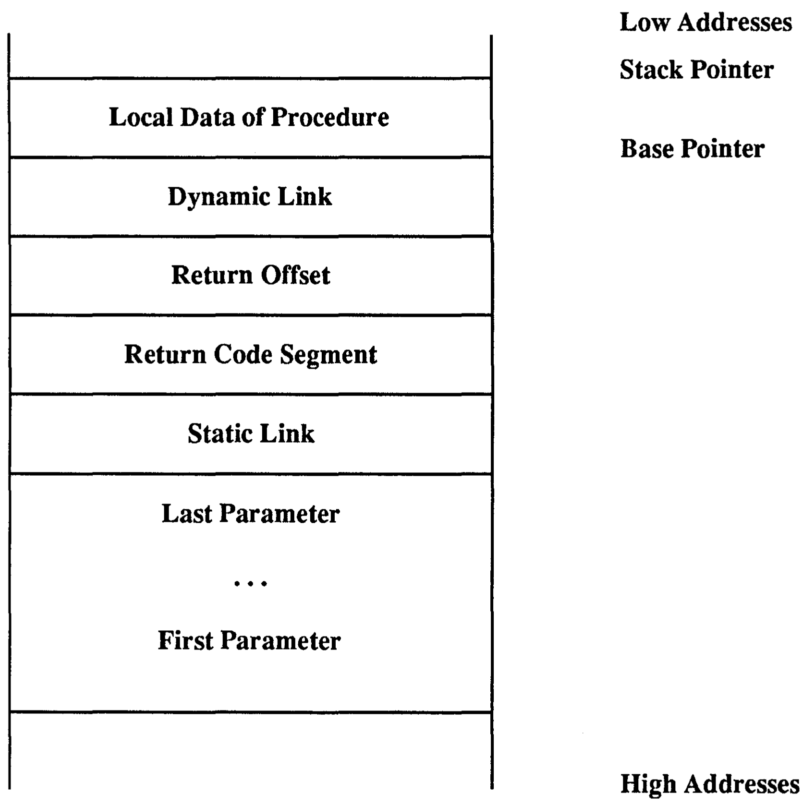


Figure B-4: Procedure Activation Record for 8086/8088

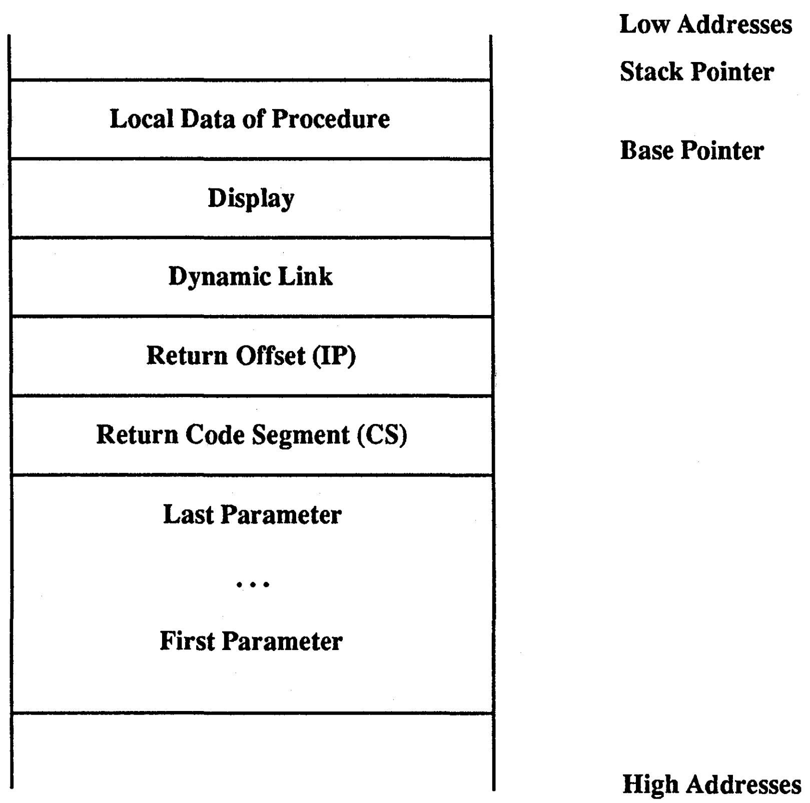


Figure B-5: Procedure Activation Record for 80186/80286

B.9 Procedure Calling Conventions

A procedure is called with a **far** intersegment call if at least one of the following conditions is true:

- It is imported from another separately compiled module.
- It is exported from a definition module.
- It is used in an assignment to a procedure variable or as a procedure parameter.
- It is used as the body (starting point) of a process upon a call to NEWPROCESS.

If none of these conditions is true, the procedure is called with a **near** intrasegment call.

Before a procedure call occurs, this prologue is executed in the calling procedure:

- Parameters, if any, are pushed on the stack in the same order as they are declared. A value parameter on one byte occupies two bytes on the stack, with the value in the low byte and an undefined high byte.
- for *8086/8088* only:
  If the called procedure is declared nested inside of the calling procedure, the static link is pushed on the stack.

This sets up the first part of the procedure activation record. The remainder is set up inside the called procedure.

Now, the procedure is called and gains control. It executes the following procedure prologue, to prepare the rest of the procedure activation record:

- An optional call to the run-time support routine stack check is executed. BX contains the number of bytes on the stack needed by the current procedure. This amount includes the size of local variables and the stack space needed to pass parameters to called procedures.

The following steps are executed for *8086/8088*:

- The current value of the base pointer BP is pushed on the stack. This sets up the dynamic link.
- The value of base pointer BP is set to the current value of stack pointer SP.
- Space is reserved on top of the stack for the local variables of the procedure, if any exist, by reducing the current value of the stack pointer SP by the total size of the procedure variables.

This is the code generated for *80186/80286*:

- The instruction **ENTER size, level** is executed where **size** is the total size of the procedure variables, and **level** is the lexical nesting level of the procedure. This instruction automatically sets up the dynamic link, the display, the space for the local variables on the stack, and the values for BP and SP.

The statements of the procedure body are then executed. The local variables and the parameters of the procedure are accessed with an offset relative to the base pointer BP.

Upon termination of the procedure body, the procedure epilogue is executed, performing the following operations:

The following steps are executed for *8086/8088*:

- The stack pointer SP is reset to the current value of the base pointer BP. This removes the local variables from the stack.
- The dynamic link is popped to restore the old value of the base pointer BP.

This is the code generated for the *80186/80286*:

- The instruction **LEAVE** is called. **LEAVE** automatically removes local variables, display, and dynamic link and resets BP and SP.
- A return instruction passes control back to the calling procedure. A **far** or **near** return is used, according to the type of call that was used to activate the procedure. The parameters and the static link are discarded automatically with the return instruction.

B.10 Function Results

A function result is returned as follows, depending on the size of the function type:

- One byte values are passed back in register AL.
- Two byte values are passed back in register AX.
- Four byte values are passed back in register DX and in register AX.
- REAL values are always passed back on top of the stack.

NOTE

In the current release, arrays and record types are not allowed as function types.

SET types bigger than a word are treated as structures.

B.11 Symbols in .OBJ Files

Here are the exact symbol definitions that the *LOGITECH Modula-2* compiler puts in the object file. These can be used for symbolic debugging, or correcting linker symbol errors. The *LOGITECH* debuggers show you the names of variables or procedures you declared, without prefix and suffix. Symbols are truncated to 31 characters (the limit of the *DOS* linker and of some assemblers). The generated symbols are case-sensitive.

Type of Symbol	Name
Exported procedure	`L__<procnam>__<modname>`
Local procedure	`S__<procnam>__<...>...`
Nested procedure	`N__<procnam>__<...>...`
Global variable	`<varnam>__<modname>`
Beginning of module	`$BM__<modname>`
End of module	`$EM__<modname>`
Beginning of data of a module	`$BD__<modname>`
End of data of a module	`$ED__<modname>`
Beginning of initialization code if in different segment	`$BI__<modname>`
End of initialization code	`$EI__<modname>`
Note: These symbols are neither used nor generated, but are reserved.	
Initialization entrypoint	`$INIT__<modname>`
Module entrypoint after initialization	`$BODY__<modname>`
Code of a local module	`$BODY__<modname>`
Key for version checking at link time	`KEY__<dateSYMfile>_OF_<modname>`
Key for version checking at run time	`$OK__<dateOBJfile>_OF_<modname>`
Beginning of a Modula-2 program	`Start Modula`
Description of a Modula-2 program	`$DD`

`KEY__` uses two underline characters with no break;
`<date of file>` uses the position-sensitive format `ddmmmyyy_hhmm` where;

`dd` = the day;	`mmm` = month;	`yy` = year;
"_" is a separator;	`hh` = the hour;	`mm` = the minute.

B.12 Aborting LOGITECH Modula-2 Programs

When you type Ctrl-Break or Ctrl-C, the operating system usually aborts the program that is currently running. Ctrl-Break and Ctrl-C have the same effect in *LOGITECH Modula-2*. However, depending on the circumstances, there are some restrictions on their use.

In general, Ctrl-C only has an effect when the program is waiting for keyboard input. Ctrl-Break cannot be used when the program is waiting for input, but can be used any other time. Ctrl-Break is immediately effective — it is acted upon as soon as you use it. The effect of Ctrl-C is delayed until the program reads the Ctrl-C character. By typing Ctrl-Break it is possible to stop a *Modula-2* program that is running in an infinite loop. However, under certain circumstances, the whole system might crash if Ctrl-Break was accepted. *LOGITECH Modula-2* tries to prevent this from happening. Therefore, typing Ctrl-Break will sometimes have no effect at all.

In *LOGITECH Modula-2*, the **Break** library module lets you define how a program will behave when you press Ctrl-Break or Ctrl-C is typed. If the **Break** and the **DebugPMD** modules are linked into a program, a memory dump (file MEMORY.PMD) will be generated when you press Ctrl-Break or Ctrl-C. To debug a program with the symbolic post-mortem debugger, a memory dump is needed. To be linked with a *Modula-2* program, you must explicitly import the **Break** module into one of the program modules. Normally, you will import it in the main module of the program. If the **Break** or **DebugPMD** modules are not linked with a program, no memory dump will be generated when you use Ctrl-Break or Ctrl-C to terminate the program, but the program will stop anyway, if possible.

With the **Break** module, you can also keep a program from aborting by having it ignore Ctrl-Break and Ctrl-C. You can also install a **Break** procedure which will be called when you press Ctrl-Break or Ctrl-C. With a **Break** procedure, a dump will not be generated automatically. When the **Break** module is used, pressing Ctrl-Break once, in almost all cases, stops the program or calls the installed break procedure.

B.13 Command Line Arguments

When a *LOGITECH Modula-2* program is executed using the executable file name prefix and the ↵, any text which follows the file name is taken as keyboard input. This means that you can type, for example:

```
M2COMP MY_PROG/BATCH/NOAQUERY ↵
```

This works for any *LOGITECH Modula-2* program that does keyboard input using the **Terminal** or **InOut** modules . You can also include this facility in your own program. When you use a read routine like **ReadString**, it will automatically read the command line.

This lets you use *LOGITECH Modula-2* programs more easily with the *DOS* Batch files, which only recognize program input on the command line. Because the compiler, linker and debugger accept either a space or a ↵ to terminate an argument, multiple arguments may be given on the command line. For example:

```
M2L OVERLAY1 (MAINLINE) ↵
```

Appendix C
Technical Tips

C.1 Print Time and Date

The following is an example of how to get the Time and Date from the system in a legiable format. Some math manipulation has to be done to extract the information from the Time record.

```
MODULE PrintTimeDate;

FROM TimeDate IMPORT
  Time, GetTime;
FROM InOut   IMPORT
  WriteCard, WriteLn, WriteString;

VAR
  curtime       : Time;
  tday, tmonth,
  tyear, ttemp,
  hr, min       : CARDINAL;

BEGIN

   GetTime(curtime);
   tday := curtime.day MOD 32;
   ttemp := curtime.day DIV 32;
   tmonth := ttemp MOD 16;
   ttemp := curtime.day DIV 512;
   tyear := ttemp MOD 128;
   hr := curtime.minute DIV 60;
   min := curtime.minute MOD 60;
   WriteString('The Time is ');
   WriteCard(hr,2);
   WriteString(':');
   WriteCard(min,2);
   WriteLn;WriteLn;
   WriteString('The Date is ');
   WriteCard(tmonth,2);
   WriteString('/');
   WriteCard(tday,2);
   WriteString('/');
   WriteCard(tyear,2);
   WriteLn;
END PrintTimeDate.

(*
   The printout has the following format:

   The Time is 14:25
   The Date is  8/ 5/87
*)
```

C.2 Printing

This is one way of getting output on the printer

```
MODULE Printing;


  FROM FileSystem IMPORT
    Lookup, Close, File, WriteChar, Response;

  FROM InOut IMPORT
    WriteString, WriteLn;

  VAR
    printer : File;
    str     : ARRAY [0..9] OF CHAR;

  PROCEDURE PrintString(str: ARRAY OF CHAR);

  VAR
    i: CARDINAL;

  BEGIN
     i:=0;
    WHILE (i<= HIGH(str)) AND (str[i]<>0c) DO
      WriteChar(printer,str[i]);
      INC(i);
    END;
  END PrintString;

  PROCEDURE OpenPrinter;

  BEGIN
    Lookup(printer,'PRN', FALSE);
    IF printer.res <> done THEN
      WriteString("cannot open 'PRN'");
      WriteLn;
      RETURN;
    END;
  END OpenPrinter;

BEGIN
  str := 'It works!';
  OpenPrinter;
  PrintString(str);
  Close(printer);
END Printing.
```

C.3 The Screen

This is one way of writting to the screen memory. The location of the screen memory depends on your Video Adaptor Card.

For Monochrome Adaptors it is **0B000H:0H**
For Color Graphic Adaptors it is **0B800H:0H**]

```
MODULE Screen;

CONST
   MAXCOL = 79;
   MAXROW = 23;

TYPE ScreenType =
          ARRAY[0..MAXROW] OF
          ARRAY[0..MAXCOL] OF
          RECORD char,attr : CHAR END;

VAR
   screen[0B000H:0H]:ScreenType;

  PROCEDURE WriteToScreen(str: ARRAY OF CHAR);

  VAR i : CARDINAL;

  BEGIN
    i := 0;
    WHILE (i<=HIGH(str)) AND (str[i]<>0c) DO
    screen[12,37+i].char := str[i];          (* Starts writting approximately
                                                in the center of the screen *)
    INC(i);
    END;
  END WriteToScreen;


BEGIN

   WriteToScreen('Hello');

END Screen.
```

C.4 Redirect Input

This is an example of how to use the redirection capability of **Termbase** module. Refer to a textbook on ***Modula-2*** if you don't understand the mechanism of procedure parameters as used by **AssignRead**.

```
DEFINITION MODULE RedirectInput;

EXPORT QUALIFIED SetInput;

PROCEDURE SetInput(str: ARRAY OF CHAR);

END RedirectInput.

IMPLEMENTATION MODULE RedirectInput;
FROM   InOut  IMPORT  OpenInput;
FROM Termbase IMPORT UnAssignRead,
  AssignRead, ReadProcedure, StatusProcedure;
FROM  ASCII   IMPORT EOL;

VAR
    InputString: ARRAY [0..80] OF CHAR;
    StringIndex   : CARDINAL;

PROCEDURE Read(VAR ch:CHAR);

BEGIN
  IF (StringIndex<=HIGH(InputString)) AND
       (InputString[StringIndex]<>0c)          THEN
    ch:=InputString[StringIndex];
    INC(StringIndex);
  ELSE
    ch:=EOL;
  END;
END Read;

PROCEDURE Status(): BOOLEAN;

BEGIN
  RETURN TRUE;
END Status;

PROCEDURE SetInput(str: ARRAY OF CHAR);

VAR i: CARDINAL; done: BOOLEAN;
```

```
BEGIN
   i:=0;
   WHILE (i<=HIGH(str)) AND (i<=HIGH(InputString)) AND (str[i]<>0c) DO
     InputString[i]:=str[i];
     INC(i);
   END;
   IF (i<=HIGH(InputString)) THEN InputString[i]:=0c END;
   StringIndex:=0;
   AssignRead(Read,Status,done);
   OpenInput(".TXT");
   UnAssignRead(done);
END SetInput;

END RedirectInput.
MODULE Example;
(*
   This program is an example of redirection and it uses MODULE
   RedirectInput. Before you run this program create a file which
   has the string(text). This program reads the string from a
   file(example.txt) and displays it on the screen.

*)
FROM RedirectInput IMPORT SetInput;
FROM     InOut     IMPORT ReadString, WriteString;

VAR str: ARRAY [0..80] OF CHAR;

BEGIN
  SetInput("example.txt");  (* example.txt contains the string *)
  ReadString(str);          (* Reads the string untill a blank is encounterd *)
  WriteString(str);
END Example.
```

Appendix D
Product Support Plan

Copy Protection

The *LOGITECH Modula-2* disks are not copy-protected. This doesn't mean you can make unlimited copies of them. *LOGITECH Modula-2* software is protected by the copyright laws that pertain to computer software. It is illegal to make copies of the contents of these disks, except for your own backup, without written permission from **LOGITECH, Inc.** *In particular, it is illegal to give a copy to another person.*

Reminder

Remember to send your registration card, if you haven't done that. It helps us to keep our contact with you, and keeps you up-to-date with important product information.

Technical Support

LMIS

We know that effective communication with our customers is the key to quality service. Therefore we have set up the **LMIS** (LOGITECH Mouse/Modula-2 Information Service), an electronic bulletin board where you can contact us at *your* convenience. To logon to the **LMIS**, dial:

(415) 795-0408

using a 300, 1200 or 2400 baud modem.

The menu of available options is self explanatory.

BIX

LOGITECH also sponsors an electronic conference on ***BIX***, the BYTE INFORMATION EXCHANGE system from ***Byte*** magazine. If you have access to ***BIX***, join us in the **LOGITECH** conference, and communicate with us there.

Getting Help through the Hotline

You should rely on your manual or your dealer to answer questions about using your package. If you do encounter a technical problem with your package, our Technical Support Specialists will be glad to help you.

We ask you to follow these steps before you call or write.

- Read the section of the manual that describes the procedure you are trying to perform.
- If the problem relates to your software, check to make sure that the software is properly configured.

If, after following these steps, you are still not able to solve the problem, give us a call at *(415) 795-0427*, or write to us. If you write, please include your daytime phone number and the best time to reach you. Also, please add "*Attn: Technical Support*" somewhere on the envelope.

We want to help you make the most effective use of your package.

A LOGITECH Modula-2 Glossary

In *LOGITECH Modula-2*, these terms have specific meanings:

Base layer
A program which calls a subprogram. For example, the compiler passes made by the overlay version of the *LOGITECH Modula-2* compiler are called sequentially by the compiled base which is their base layer.

Compilation unit
Part of a program contained in a separate file which can be compiled separately. *Modula-2* compilation units are: definition, implementation, and program modules. Modules can be compiled separately only if the imported definition modules are already compiled. Only definition modules can export objects. If an object is exported from a compilation unit, it must be split into definition and implementation modules.

Definition module
The definition part of a *Modula-2* module. For more information on definition modules, refer to the corresponding sections in *Programming in Modula-2* by Niklaus Wirth.

Development system
The entire system, both hardware and software, used to develop a program. Software includes the operating system and utility programs and libraries. When used to develop *Modula-2* programs, it includes *Modula-2* run-time support, as well as the *Modula-2* compiler, linker, debuggers, editor, utilities, and library.

Language support

A program seen as an extension to the hardware. It gives the target system the ability to execute programs written in the corresponding programming language. The language support for ***Modula-2*** is part of the ***Modula-2*** run-time support.

Library

In general, a library is a set of functions or procedures which can be used by any program. In ***Modula-2*** the library is equal to the set of all available ***Modula-2*** library modules.

Library module

A ***Modula-2*** module, consisting of a definition and an implementation part, which is available for use by any ***Modula-2*** program.

Implementation module

The implementation part of a ***Modula-2*** module. An implementation module contains the code that implements the capabilities provided by this module as they are specified by the corresponding definition module. The section on basic concepts in this manual contains a brief description of implementation modules. For more on the use of implementation modules refer to the corresponding sections in ***Programming in Modula-2*** by Niklaus Wirth.

Main module

The main module of a ***Modula-2*** program is the module that is given to the linker to link the program. The module code of the main module constitutes the main program. The main module must be a program module.

Main program

The term 'main program' has two different definitions depending on the context in which it is used:

When talking about a single program, it refers to a particular part of the code of that program, the main program code. Executing the main program code is equivalent to executing the whole program. In ***Modula-2***, the main program code consists of the program module. The execution of a program starts with the execution of its main program code. When the execution reaches the end of the main program code, the program terminates.

When talking about programs and subprograms, the term *main program* refers to a program that is the base layer of a (set of) subprogram(s), and that is not a subprogram itself.

Objects

Anything that can be given a name, including constants, variables, procedures, types, and modules.

Overlay

A part of the code of a program is an overlay of that program, if this code is loaded at the same memory location as some other code - the code of another overlay - of the same program. When code that belongs to an overlay is loaded into memory, it *overlays* the code of the overlay that was loaded previously. Sometimes, not only code but also data is overlayed.

By using overlays, a program that would require a large amount of memory can run on a computer with less memory. ***Modula-2*** provides a simple overlay concept in the form of subprograms.

Program

A ***Modula-2*** program with all the modules which are imported directly or indirectly by its main module. When a program is linked, the resulting load file includes all these modules. A ***Modula-2*** program may also call another ***Modula-2*** program as a subprogram. A program that calls a subprogram, but is not a subprogram itself is also called a main program. In this context, the term *program* refers to the one main program and the set of all its subprograms.

Program module

A ***Modula-2*** module which does not have a definition module and is not declared in any other module. The code of a program module is a main program. For more information on program modules please refer to the corresponding sections in the book *Programming in Modula-2* by Niklaus Wirth.

RTS **(Run-time support)**

A set of modules which includes language support and other configuration-dependent functions. These include typical operating system features such as setting up the memory configuration, loading programs, and dumping memory to disk.

Separately compiled module (SCM)

A compilation unit which is either an implementaion or a program module, and has been compiled separately.

Subprogram

A ***Modula-2*** program called by another ***Modula-2*** program. A subprogram consists of those modules imported directly or indirectly by its main module which are not part of its base layer. A subprogram can use objects exported by the modules of the calling program. A subprogram may also call other subprograms. Subprograms in ***Modula-2*** provide a very simple overlay concept. For information on how to call subprograms, please refer to the definition module 'Program' in the library section of this manual. For information on the memory use of subprograms, refer to the appendix on memory organization.

Target system

The system, both hardware and software, on which you execute your application programs. In most cases the target system is the same as the development system. However, this is not a requirement. The hardware configuration of a target system for ***Modula-2*** or ***Modula-2/VX86*** does not require a terminal or disks. The software configuration may be reduced to the ***Modula-2*** run-time support and your program.

Workspace

The memory region allocated to a process for stack, program variables, heap, and subprograms. When a ***Modula-2*** program is started, it begins execution as the *main process*. The default stack size of any main program is 8000 bytes. This value can be modified at link time. A subprogram shares the workspace (stack) of its base layer. When a process is created, the workspace is defined as a parameter of SYSTEM NEW PROCESS. It may be located anywhere, (loop, stack, or global data). Just don't let the process have a longer lifetime than its workspace!

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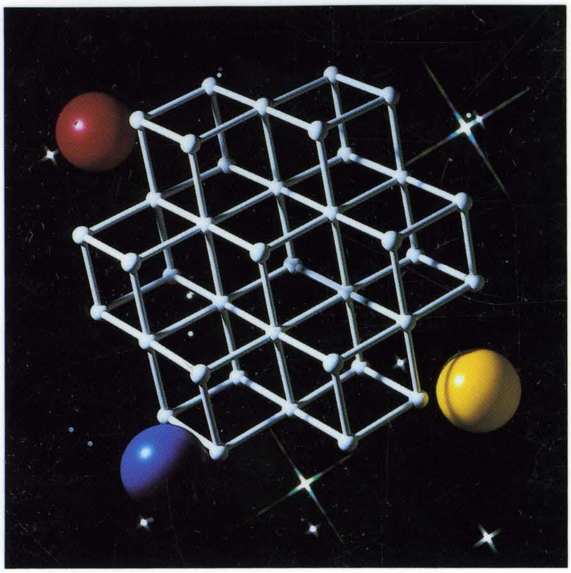

USER'S MANUAL

Compiler
Library
Post Mortem Debugger

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