GFK-0771

GE Fanuc Manual Series 90-30

C Programmer s Toolkit for Series 90 PCMs

GE Fanuc Automation

Programmable Control Products

C Programmer's Toolkit for Series 90™ PCMs

User's Manual

GFK-0771A *August 1996*

Warnings, Cautions, and Notes as Used in this Publication

Warning

Warning notices are used in this publication to emphasize that hazardous voltages, currents, temperatures, or other conditions that could cause personal injury exist in this equipment or may be associated with its use.

In situations where inattention could cause either personal injury or damage to equipment, a Warning notice is used.

Caution

Caution notices are used where equipment might be damaged if care is not taken.

Note

Notes merely call attention to information that is especially significant to understanding and operating the equipment.

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Preface

This manual contains essential information about the design and construction of C language application programs for the GE Fanuc Series 90™ Programmable Coprocessor Module (PCM). It is written for experienced C programmers who are also familiar with the operation of Series 90 PLCs. Readers new to the C programming language or to Series 90 PLCs should familiarize themselves thoroughly with these topics before attempting to use the material in this manual. The list of publications at the end of this section contains helpful references.

General information on PCM hardware, its installation and operation, and connecting a personal computer (PC) to a PCM can be found in the *Series 90 Programmable Coprocessor Module and Support Software User's Manual*, GFK-0255, revision D or later.

Content of this Manual

Chapter 1. Introduction: Chapter 1 describes the PCM C toolkit and lists some types of applications which have been successfully implemented in C on the PCM.

Chapter 2. Installation: Chapter 2 lists the items you will need to develop PCM applications in C, explains how to install the PCM C toolkit, and describes how Microsoft® C version 6.00 must be installed.

Chapter 3. Creating and Running PCM C Programs: Chapter 3 describes the creation and installation of a simple C program for the PCM.

Chapter 4. Using PCM Resources: Chapter 4 describes how to use the hardware resources of the PCM, the facilities of its VTOS operating system, and services provided by the PLC CPU from C applications.

Chapter 5. PCM Libraries and Header Files: Chapter 5 lists all the services provides by the PCM C libraries and the C header files which describe them to the C compiler.

Chapter 6. PCM Real Time Programming: Chapter 6 describes some important issues in real time communication and control applications, and how to address them in PCM applications.

Chapter 7. Multitasking: Chapter 7 describes how to use multiple PCM tasks to design a real time application, and how to run two or more independent applications in the same PCM.

Chapter 8. Memory Models: Chapter 8 describes the memory models which the PCM supports.

Chapter 9. Example Programs: Chapter 9 describes the sample programs provided with the PCM C toolkit.

Chapter 10. Applications In ROM: Chapter 10 describes how to install PCM applications in PCM Read–Only Memory (ROM).

Chapter 11. Utilities: Chapter 11 describes the utility programs provided with the PCM C toolkit.

Chapter 12. GE Fanuc Support Services: Chapter 12 describes the consultation services provided by GE Fanuc to each purchaser of the PCM C toolkit.

Appendix A. Microsoft Runtime Library Support: Appendix A lists all the functions provided in the Microsoft C 6.00 runtime libraries, and indicates which ones are applicable to the PCM.

Appendix B. PCM Commands: Appendix B is a complete reference to the PCM command interpreter.

Appendix C. Batch Files: Appendix C describes how to control PCM operation with batch files.

Appendix D. PCM C Directories and Files: Appendix D lists all the directories and files created on your hard disk during installation of the PCM C toolkit.

Related Publications

For more information, refer to these publications:

Series 90™ -70 Programmable Controller Installation Manual (GFK-0262): This manual describes the hardware used in a Series 90-70 PLC system, and explains system setup and operation.

Logicmaster™ 90-70 Programming Software User's Manual (GFK-0263): This manual describes operation of Logicmaster 90-70 software for configuring, programming, monitoring, and controlling a Series 90-70 PLC and / or remote I / O drop.

Series 90™ -70 Programmable Controller Reference Manual (GFK-0265): This manual describes program structure and instructions for the Series 90-70 PLC.

S***eries 90™ -30 Programmable Controller Installation Manual*** (GFK-0356): This manual describes the hardware used in a Series 90-30 PLC system, and explains system setup and operation.

Logicmaster™ 90 Series 90-30 and 90-20 Programming Software User's Manual (GFK-0466): This manual describes operation of Logicmaster 90-30 software for configuring, programming, monitoring, and controlling a Series 90-30 PLC.

Series 90™ -30/90-20 Programmable Controllers Reference Manual (GFK-0467): This manual describes program structure and instructions for the Series 90-30 PLC.

PCM C Function Library Reference Manual (GFK-0772): This manual provides a complete reference to all the library functions provided in the PCM runtime libraries for the PCM C toolkit.

The C Primer. Hancock, Les, and Morris Krieger. New York: McGraw-Hill Book Co., Inc., 1982.

C: A Reference Manual. Harbison, Samuel P., and Greg L. Steele. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., Third Edition, 1988.

The C Programming Language. Kernighan, Brian W., and Dennis M. Ritchie. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., Third Edition, 1988.

Programming in C. Kochan, Stephen. Hasbrouck Heights, New Jersey: Hayden Book Co., Inc., 1983.

Learning to Program in C. Plum, Thomas. Cardiff, New Jersey: Plum Hall, Inc., 1983.

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Henry Konat
Senior Technical Writer

Chapter 1 Introduction

The C Programmer's Toolkit for Series 90™ PCM (the PCM C toolkit) contains header files, libraries, utility programs, and documentation required to design and construct C language applications for the Series 90 Programmable Coprocessor Module (PCM). These applications are developed on a standard personal computer (PC) and then installed in battery-backed RAM or EPROM in a PCM.

Why Develop PCM Applications In C?

The PCM has supported the MegaBasic programming language since its introduction. MegaBasic is an interpreted language. Although it is relatively fast in comparison to other interpreted languages, MegaBasic is considerably slower than compiled C code.

OEMs can install C applications in EPROM, making more efficient use of PCM RAM space.

C applications can use multiple PCM tasks to efficiently handle external events.

Appropriate Applications

A PLC CPU is optimized for control processing. However, many PLC applications include some computation-intensive information processing which is not well suited to the PLC CPU environment. These applications can often be optimized by moving the computation out of the CPU. The Series 90 PCM family provides a platform for hosting this kind of processing within PLCs. PCMs offer these features to support PLC applications:

1. A PCM provides an independent processing platform which is not directly bound by PLC sweep time constraints.
2. Each PCM provides two serial communication ports for the PLC application.
3. PCMs can read PLC process data; they can also change it.
4. The PCM operating system, VTOS, is optimized for real-time processing based on the finite state machine abstraction.
5. PCMs provide a wide range of optional memory. Applications can store up to 618 Kbytes of process data.
6. PCM applications can store data as files in the PCM RAM disk file system or in a personal computer (PC) attached to a PCM serial port.

A number of C applications are already at work in PCMs or nearing completion. The application areas include:

- Serial communication nodes for assorted protocols.
- Drivers for operator interface terminals.
- Boiler controls.
- Electric power control and monitoring.
- Automatic assembly machine control.
- Tank truck loading station controls.
- Controls for integrated circuit fabrication equipment.

Limitations

The Series 90-70 PCM is approximately equivalent in computing throughput to an 8 Mhz. 80286-based personal computer. The three Series 90-30 PCM models are all about half as fast as the Series 90-70 PCM. There is no hardware support for floating point math coprocessor chips.

C applications in RAM have a bit more than 600 Kbytes available for code and data. Nearly 128 Kbytes of EPROM space is available for code and constant data in both series.

Expertise Required

Successful C programming for the PCM requires a thorough understanding of advanced topics like mixed memory model programming, event-driven finite state machines, re-entrancy, and concurrency, among others. Familiarity with Series 90 PLCs is also required.

The PCM includes a multitasking operating system, VTOS, which is designed to handle asynchronous events like communication and operator interaction behind the scenes. Effective PCM applications tend to use multiple tasks and multiple execution threads within tasks.

By contrast, MS-DOS encourages a single-threaded, “polling loop” style of program design. However, PCM applications designed in this way are substantially slower than they could be. C programmers whose experience is limited to MS-DOS applications should read and thoroughly understand the material in chapters 6 and 7 of this manual before undertaking PCM programs.

Getting Started

The remaining chapters in this manual contain information on various aspects of C program development for PCM applications. Depending on your background, you may already be familiar with the material in some chapters. Here is a list of the chapters with recommendations on who should read each one.

Chapter 2 covers the installation of the PCM C toolkit on your PC. You should start here if the software has not been installed.

Chapter 3 is a step-by-step introduction to the process of compiling, linking, loading, and running PCM C applications. If you are not familiar with these procedures, you should go through each step on your PC while you read chapter 3.

Chapter 4 is an overview of PCM features available to C programmers. All PCM C developers need to understand these features.

Chapter 5 is an overview of PCM C libraries and the C header files which support the PCM features described in chapter 4. It is a good starting point for answers to "How do I ... ?" questions.

Chapter 6 is a discussion of PCM support for real-time, event-driven applications like communication, interactive terminal drivers, and process control. Anyone who develops real-time PCM applications should read and understand this material.

Chapter 7 describes PCM multitasking, its uses, and special considerations for debugging applications with multiple tasks. Developers of real-time applications will need to read it carefully, but all PCM C developers should understand the ideas in this chapter.

Chapter 8 is a discussion of memory models supported by the PCM. There are code size, performance, and ease-of-use tradeoffs between memory models; all PCM C programmers should understand these issues.

Chapter 9 contains several example programs, along with discussion of their design and applicability. Most C developers should find a starting point for their project here.

Chapter 10 explains how to install PCM applications in EPROM. OEMs will find this chapter useful.

Chapter 11 is a reference for the utility programs provided with the PCM C toolkit. The basic operation of these utilities is covered in other chapters.

Chapter 12 details the support services provided by GE Fanuc to purchasers of this development software.

Appendix A is a complete list of Microsoft C Version 6.0 library functions, and includes the level of support for each function in the PCM. Everyone will use this material on an as-needed basis.

Appendix B is a complete reference to the commands supported by the PCM command processor for configuration and operation of the PCM. This material is also useful on an as-needed basis.

Appendix C describes PCM batch files, which use the commands in appendix B to control the operation of the PCM when it is powered on or reset. This material is not unique to C applications. All PCM developers should be familiar with it.

Appendix D is a list of the directories and files created when this software is installed. A short description of each file is also provided.

Chapter 2 Installation

This chapter describes the installation process for the PCM C toolkit.

What You Will Need

These hardware items are required to develop C applications for PCMs:

- A GE Fanuc Series 90 PLC containing at least one PCM;
- An IBM PC, PC XT, PC AT or PS / 2; GE Fanuc Workmaster, Workmaster II, or CIMSTAR I industrial computer; or other IBM-compatible, MS-DOS® / PGDOS based personal computer (PC) with a hard disk and at least one RS-232C serial port, running MS-DOS 3.3 or later. Your computer must have enough unused hard disk capacity to install Microsoft® C (up to 25 megabytes, depending on your version and what you choose to install) and the PCM C toolkit software (about 600K bytes), and to develop your PCM applications. If you care about your productivity, you will want an 80386 or 80486-based computer, MS-DOS 4.0 or 5.0, and a fast hard disk.

  You can install the toolkit software from a DOS window under Microsoft Windows® 3.x, but not under Windows 95 or Windows NT. If your computer runs Windows 95, restart your computer in MS-DOS mode. If your computer runs Windowsx NT, you must install DOS and then configure your computer to boot either Widows NT or DOS
- A serial cable to connect the PCM and PC.

These GE Fanuc products are also required to develop PCM C applications:

- PCM Support Software (TERMF), revision 1.00 or later, is required for terminal emulation and file transfer between the PC and PCM;
- Logicmaster 90 Configuration Software is required to set the PCM configuration mode for C applications.

These items, which are not furnished by GE Fanuc, are required for PCM C development:

- Microsoft C Version 6.0, Microsoft C / C++ Version 7.0, or a 16-bit version of Microsoft Visual C / C++ Professional Edition.
- A text editor such as the Microsoft Editor (EDIT.COM), furnished with Microsoft MS-DOS Version 5.00.

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Microsoft C Installation Requirements

Microsoft C must be installed before the PCM C toolkit. There are two requirements for installing Microsoft C.

1. You must select the Alternate Math package during installation. When you run the Microsoft C SETUP program, you will encounter this line:

   ```
   Math options:  Emulator [Y]: N   8087 [N]: N   Alt Math [N]: Y
   ```

   You must answer "**Y**" to "**Alt Math**". You may also wish to install the Emulator and / or 8087 math package, but they are not useful for PCM applications.

2. The Microsoft C SETUP program attempts to modify the AUTOEXEC.BAT file in the root directory of your boot drive (normally C:\). SETUP tries to modify the SET commands, if any, which definine the environment variables LIB and INCLUDE. If there are no SET commands defining them, SETUP will attempt to add them.

The PCM C toolkit relies on these environment variables for finding Microsoft library files (such as SLIBCE.LIB, etc.) and include files (such as CTYPE.H, etc.). If SETUP does not add the definitions for these environment variables to your AUTOEXEC.BAT file, you will need to do it manually. See "Adding \PCMC\LIB to Your LIB Environment Variable" and "Adding \PCMC\INCLUDE to Your INCLUDE Environment Variable" later in this chapter.

Caution

PCM C applications which use floating point math must be compiled with the Microsoft C Alternate Floating Point math (/FPa) command line switch, and the alternate math library must be installed. If you have already installed Microsoft C without the alternate math library, you must run the Microsoft C SETUP program again to install it.

Microsoft Quick C does not support the alternate math package. PCM C applications which use floating point math cannot be compiled with Quick C.

Installing the PCM C Toolkit

To install the Series 90 PCM C toolkit, insert the GE Fanuc distribution diskette into a diskette drive of your personal computer. If you have more than one diskette drive, you can use any one of them. Then, at the DOS prompt, type: **A:INSTALL** or **B:INSTALL**, depending on which diskette drive you are using. The installation program will prompt you for all required information, including the hard disk drive where you want to install the toolkit.

A complete list of the directories and files which were created on your hard disk during the installation process can be found in appendix D of this manual.

During the installation process, a new version of AUTOEXEC.BAT is created on the hard drive and directory where the PCM C toolkit is installed. The INSTALL program asks you whether to replace the copy of AUTOEXEC.BAT in the root directory of your computer's boot drive (in this case, C):

```
Copy \PCMC\AUTOEXEC.BAT to C:\AUTOEXEC.BAT ?
```

If you answer "**Y**" to this prompt, the version of AUTOEXEC.BAT which INSTALL found in the root directory of your boot drive will be copied to the \PCMC directory of the drive you specified for the toolkit installation. The name of the file will be changed to AUTOEXEC.BAK. Then, the modified AUTOEXEC.BAT will be moved to the root directory of your boot drive.

If you answer "**N**" to the prompt, you must do one of two things before the toolkit will work correctly:

1. Copy the new version of AUTOEXEC.BAT to the root directory of your computer's boot drive; or
2. Change your existing AUTOEXEC.BAT file manually, as described in the following sections.

Adding \PCMC to Your MS-DOS Path

If you choose to modify your AUTOEXEC.BAT manually, you must add \PCMC to the PATH definition in your AUTOEXEC.BAT file. For example, if your PATH is currently defined as:

```
PATH=C:\;C:\DOS;C:\BIN;C:\C600\BINB;C:\C600\BIN
```

or

```
PATH=C:\;C:\DOS;C:\BIN;C:\C700\BINB;C:\C700\BIN
```

You must change it to:

```
PATH=C:\;C:\DOS;C:\BIN;C:\PCMC;C:\C600\BINB;C:\C600\BIN
```

or

```
PATH=C:\;C:\DOS;C:\BIN;C:\PCMC;C:\C700\BINB;C:\C700\BIN
```

respectively. If the PCM C toolkit was not installed on drive C, substitute the correct drive letter in the PATH command.

Adding \PCMC\LIB to Your LIB Environment Variable

If you choose to modify your AUTOEXEC.BAT manually, you must also add \PCMC\LIB to the definition of your LIB environment variable **before** the Microsoft C library subdirectory. This variable tells the Microsoft linker where to find PCM startup code and libraries. For example, if your LIB variable is currently defined by:

```
SET LIB=C:\C600\LIB
```

or

```
SET LIB=C:\C700\LIB
```

Then you must change it to:

```
SET LIB=C:\PCMC\LIB;C:\C600\LIB
```

or

```
SET LIB=C:\PCMC\LIB;C:\C700\LIB
```

respectively. If the PCM C toolkit was not installed on drive C, substitute the correct drive letter in the SET LIB command.

Caution

The subdirectory `\PCMC\LIB` must occur before `\C600\LIB` or `\C700\LIB` in the LIB environment variable. If it does not, your PCM applications will not execute as expected, and a PCM lockup may occur.

Adding \PCMC\INCLUDE to Your INCLUDE Environment Variable

Finally, if you choose to modify your AUTOEXEC.BAT manually, you must add \PCMC\INCLUDE to the definition of your INCLUDE environment variable. It must occur **before** the Microsoft C INCLUDE subdirectory. For example, if your INCLUDE variable is currently defined by:

```
SET INCLUDE=C:\C600\INCLUDE
```

or

```
SET INCLUDE=C:\C700\INCLUDE
```

Then you must change it to:

```
SET INCLUDE=C:\PCMC\INCLUDE;C:\C600\INCLUDE
```

or

```
SET INCLUDE=C:\PCMC\INCLUDE;C:\C700\INCLUDE
```

respectively. If the PCM C toolkit was not installed on drive C, substitute the correct drive letter in the SET INCLUDE command.

Caution

The subdirectory \PCMC\INCLUDE must occur before \C600\INCLUDE or \C700\INCLUDE in the INCLUDE environment variable. If it does not, your PCM applications will not execute as expected, and a PCM lockup may occur.

Switching Between PCM and MS-DOS Application Development

These changes to the INCLUDE and LIB environment variables are necessary to guarantee that Microsoft C will find the correct include files and libraries for PCM C applications. When you develop C applications for MS-DOS, you will need to change these environment variables before compiling or linking. Two batch files in the \PCMC subdirectory, PCMC.BAT and DOSC.BAT, are provided for redefining the INCLUDE and LIB environment variables to the correct values for PCM and MS-DOS C development, respectively.

These batch files are created automatically during the installation process. They reflect the hard drives and directories where the PCM C toolkit and Microsoft C are actually installed.

Note

If a C application program intended for MS-DOS is inadvertently compiled and linked using the INCLUDE and LIB definitions for the PCM, the error message:

```
run-time error -- Linked for execution on a PCM, not DOS
```

will be displayed when MS-DOS runs the application.

If you load an MS-DOS program to your PCM and attempt to run it, the program will terminate immediately; no error message is printed.

Chapter 3 Creating and Running PCM C Programs

This chapter describes the process of developing C applications for the PCM. It will show you how to create a simple demonstration program and run it in your PCM.

Creating C Source Files

C language source files are created using a text editor. Any editor which produces text files using only the seven-bit ASCII character set may be used. Some word processors embed control characters in the text or set the high order bit of text characters. If you use one of these programs, the Microsoft compiler will complain about invalid characters.

A text editor, called EDIT.COM, is provided with Microsoft MS-DOS Version 5.00. It works reasonably well.

The source file for the demonstration is \PCMC\EXAMPLES\HELLO.C, which was copied to your hard disk during the PCM C toolkit installation. Open it with your text editor; it should look like this:

```
/*
 * HELLO.C
 *
 * PCM C demonstration program
 */
#include <vtos.h>
#include <stdio.h>

void main()
{
    word task, rev;

    task = Get_task_id();
    rev = Get_pcm_rev();
    printf( "Hello, world!\n" );
    printf( "I'm running as task %02x hex under VTOS version %x.%02x.\n",
       task, rev >> 8, rev & 0xff );
}
```

If you prefer, you can type it into your editor.

The program prints its greeting and some information about where it is running. It calls three library functions: **`Get_task_id`** and **`Get_pcm_rev`** from the PCM libraries, and the standard library function **`printf`**.

Compiling Sources

An MS-DOS batch file, CC.BAT, is provided for compiling single source files. Using it is the most convenient way to compile one or two sources. The command line for using it is simply:

cc *<memory model> <file name>*

where *<memory model>* specifies the memory model you want to use, and *<file name>* is the name of your source file **without** the file extension or dot ('.') character. You can specify either "s", "m", or "l" (for Small, Medium, and Large, respectively) as the memory model. "S", "M", and "L" have the same meaning. Compiling in Small model produces smaller, faster code. You should specify "s" or "S" whenever possible. For more information on memory models, see chapter 8, *Memory Models*.

To compile our example, first copy \PCMC\EXAMPLES\HELLO.C to a working directory. Then, type: **cc s hello** at the MS-DOS prompt, and press the Enter key. You should see this on your screen:

```
Microsoft (R) C Optimizing Compiler Version 6.00A
Copyright (c) Microsoft Corp 1984-1990. All rights reserved.

hello.c
>
```

If you see:

```
Bad command or file name

>
```

your PCM C toolkit has not been installed correctly. Please review the steps in chapter 2, *Installation.*

Compiling C code for the PCM requires the use of several Microsoft C Compiler command line switches. CC.BAT remembers all of them for you. One of these switches produces a log file (for example, HELLO.OUT). When the compiler issues error or warning messages, they are placed in the log file. After compilation completes, the log file is displayed on your screen. If you see error messages, you can open the log file in your text editor while correcting the C source file.

Linking Objects

After compiling to the object (.OBJ) files, C programs must be linked with Microsoft and PCM library functions to produce an executable (.EXE) file. Linking for the PCM also requires several command line switches. To make it simple, another MS-DOS batch file, CLINK.BAT, is provided for linking a single object file. Its use is similar to CC.BAT:

```
clink <memory model> <file name>
```

where the same <*memory model*> and <*file name*> used with CC.BAT must be used again. Typing: **clink s hello** produces:

```
Microsoft (R) Segmented-Executable Linker  Version 5.10
Copyright (C) Microsoft Corp 1984-1990.  All rights reserved.

>
```

If there are linkage errors, the linker will display error messages between its invocation message and the MS-DOS prompt.

CLINK.BAT accepts up to five object files. If your application requires six or more source files, see "Using Makefiles" later in this chapter.

Specifying the Stack Size

Unlike standard MS-DOS, the PCM executes applications in ROM (Read-Only Memory) as well as RAM (Random Access Memory, which can be read and written). One consequence of this feature is that the PCM cannot use the MS-DOS method for specifying program stack size. Instead, each PCM .EXE file has a data value in its header which contains the stack size. MS-DOS uses this data for a different purpose, and the Microsoft linker always initializes the PCM stack size to 65,520 bytes. This is a very large stack for most applications, and wastes PCM memory.

A PCM C utility program, STKMOD.EXE, is used to specify the correct stack size.

Note

The Microsoft compiler and linker command line switches for specifying the stack size of MS-DOS executable files **have no effect** when used for PCM C applications. The STKMOD utility must be used instead.

The STKMOD command line is

stkmod <*exe name*> –s <*decimal stack size in bytes*>

or

stkmod <*exe name*> /s <*decimal stack size in bytes*>

where *<exe name>* is the .EXE file name, with or without the file extension and dot ('.') character, and *<decimal stack size in bytes>* specifies the stack size.

To specify a 2 Kbyte stack for HELLO.EXE, type: **stkmod hello –s 2048** at the MS-DOS prompt. STKMOD responds with:

```
       GE Fanuc Automation PCM EXE File Stack Size Utility, Version 1.00
          Copyright (c) 1992, GE Fanuc Automation North America, Inc.
                              All rights reserved.

HELLO.EXE                           (hex)    (dec)

new stack size in paragraphs        0080      128
new stack size in bytes             0800     2048
```

which shows that the stack size is now 800 hexadecimal (or 2048 decimal) bytes.

A stack size of 2048 bytes is ample for most PCM applications, although some will require more.

The minimum PCM stack size is 1024 bytes, and the maximum size is 65,520. Valid stack sizes are integer multiples of 16 bytes. If you specify a stack size which does not meet these requirements, STKMOD.EXE will adjust it for you.

The STKMOD utility can also be used to check the stack size of PCM .EXE files without changing it. Simply invoke STKMOD without a stack size value. If you type: **stkmod hello,** STKMOD responds with:

```
       GE Fanuc Automation PCM EXE File Stack Size Utility, Version 1.00
          Copyright (c) 1992, GE Fanuc Automation North America, Inc.
                              All rights reserved.

HELLO.EXE                           (hex)    (dec)

old stack size in paragraphs        0080      128
old stack size in bytes             0800     2048
```

Loading Executable Files

Executable files must be loaded to the PCM using TERMF, the PCM terminal emulation / file transfer program. TERMF is available separately from GE Fanuc Automation as catalog number IC641SWP063. For information on TERMF installation and configuration, see chapter 2, section 3, "TERMF installation and Configuration", in the *Series 90 Programmable Coprocessor Module and Support Software User's Manual*, GFK-0255D or later.

If you already have a copy of PCOP, the PCM development software package (catalog number IC641SWP061), you do not need to purchase TERMF separately. TERMF is a part of the PCOP package; it can be invoked from within PCOP with the Shift-F3 function key. Alternatively, TERMF can be started without PCOP by typing: **\PCOP\TERMF** at the MS-DOS prompt. If the \PCOP directory is in your PATH, you can simply type: **TERMF**.

Before a program can be loaded to a Series 90-30 PCM, it must be configured for either PCM CFG or PROG PRT mode. The configuration can be performed using either the Series 90-30 Hand-Held Programmer or the Logicmaster 90-30 configuration software package.

Caution

When a Series 90-30 PCM has not been configured by either the Hand-Held Programmer or Logicmaster 90-30 software, its default configuration mode is CCM communication on both serial ports. You will not be able to load or run PCM programs until the PCM has been configured for PCM CFG or PROG PRT mode.

Programs can be loaded to a Series 90-70 PCM without configuring it using Logicmaster 90-70 configuration software.

An RS-232C serial port on your computer (PC) must be connected to serial port 1 of the PCM by an appropriate serial cable. RS-232C cables for common PC serial ports are described in appendix A of the *Series 90 Programmable Coprocessor Module and Support Software User's Manual*, GFK-0255D, or later.

The serial communication settings for TERMF must be identical to the ones used by the PCM. When the PCM is configured for Logicmaster 90 PCM CFG mode, the settings are 19,200 baud, no parity, eight (8) data bits, one (1) stop bit, and hardware handshaking. In PROG PRT mode, the settings are selected by the user.

Note

PCM file transfer **requires** 8 data bits and hardware handshaking. File transfers will fail if 7 data bits or software handshaking is selected.

The TERMSET program, included with both the TERMF and PCOP software products, may be used to specify TERMF serial communication settings. See "Using TERMSET to Configure TERMF or PCOP" in chapter 2, section 3 of the *Series 90 Programmable Coprocessor Module and Support Software User's Manual*, GFK-0255D or later.

When you have connected your PC's serial port to the PCM, configured TERMF, and run it from the MS-DOS prompt, reset your PCM by pressing the Restart/Reset button and holding it for more than five (5) seconds (a hard reset). If you press the Enter key on your PC, you should see the **">"** prompt from the PCM command interpreter. Pressing the Enter key repeatedly should add another **">"** prompt on the same line each time you press it.

The command interpreter defaults to its non-interactive mode, which is used by PCOP. However, loading and running C applications is much easier in interactive mode. Type two exclamation points ("**!!**") and press the Enter key to switch to interactive mode. You should see this message:

```
     INTERACTIVE MODE ENTERED
type '?' for a list of commands


>
```

Once again, the **">"** character is the PCM prompt. If you press the Enter key at this point, you should see another **">"** prompt, separated from the first one by a blank line.

If you have trouble communicating with your PCM or getting into interactive mode, refer to appendix B, *PCM Commands*. Appendix B also includes a complete reference for PCM commands.

When TERMF is communicating with the PCM command interpreter in interactive mode, and HELLO.EXE is in your PC's current directory, you are ready to load it to the PCM. Use the PCM L (Load) command; type: **L HELLO.EXE** at the PCM prompt. You should see the middle LED on the PCM flash while the file is being loaded. When the file transfer has completed, another blank line and **">"** prompt will be displayed. Verify that the file was loaded by using the PCM D (Directory) command. HELLO.EXE should be one of the files listed:

```
>

dHELLO.EXE     0616:00A0
```

The hexadecimal numbers which follow the the file name are its entry point address. Entry points are shown only for executable files, and only if your PCM has firmware version 3.00 or later. Entry point addresses are useful for debugging C programs with hardware debuggers and for interpreting the output of the PCMDUMP utility. See chapter 11, *Utilities*, for information on the PCMDUMP utility.

Running a PCM Task

The PCM R (Run) command is used to execute an .EXE file as a PCM task. At the PCM prompt, type: **R HELLO.EXE.**

The file extension ".EXE" is required by the PCM command interpreter.

When the program is executed, TERMF will display its output:

```
Hello, world!
I'm running as task 0f hex under VTOS version 3.00.
```

The Run command can also be used to load PCM programs from your PC. If the specified .EXE file has not been stored to the PCM, the command interpreter will ask TERMF to look in the current PC directory. If the file is found there, it will be loaded and then run.

Debugging a PCM Task

PCM firmware version 3.00 does not include a runtime debugger. The best debug method currently available is to use printf statements to trace program execution and display program data. Applications which use both PCM serial ports for communication can log execution trace data to a PCM file or named memory module.

Series 90-70 PCM applications can log trace data to a reserved memory block in VME dual port memory. A second PCM can be used to read the data in VME master mode.

When an application task locks up, the PCM task state dump facility can be used to diagnose the cause. For more information on this topic, see "Dumping PCM task state information" in chapter 7, *Multitasking.*

Some developers of PCM C applications use hardware debuggers. See "Debugging Multiple Tasks" in chapter 7, *Multitasking*, for more information on hardware debuggers.

Using Makefiles

Building PCM .EXE files from two or more C sources, and building multitasking applications (with two or more .EXE files) is handled most efficiently by using either the NMAKE or NMK utility provided with Microsoft C. NMK is provided with Microsoft C 6.0, but not with Microsoft C/C++ 7.0. Some restrictions apply to NMK. See the Microsoft documentation for information on using NMAKE and NMK.

When using one of these utilities to build PCM applications, the command line options which NMAKE or NMK uses to invoke the Microsoft compiler and linker **must** be specified correctly. The file MAKEFILE.1, which was copied to your \PCMC\EXAMPLES directory during installation of the PCM C toolkit, builds HELLO.EXE. You can use it by deleting all the HELLO.* files **except** HELLO.C from your working directory, and then typing:

```
NMAKE \PCMC\EXAMPLES\MAKEFILE.1
```

or

```
NMK \PCMC\EXAMPLES\MAKEFILE.1
```

at the MS-DOS prompt. NMAKE or NMK should respond with:

```
Microsoft (R) Program Maintenance Utility   Version 1.11
Copyright (c) Microsoft Corp 1988-90. All rights reserved.

       cl /c /AS /Aw /G1 /Gs /FPa /Zl /Zp /Fchello hello.c >hello.out
Microsoft (R) C Optimizing Compiler Version 6.00A
Copyright (c) Microsoft Corp 1984-1990. All rights reserved.

       type hello.out
hello.c
       link /NOD/NOE/M crt0sm hello.obj chkstks ifcallsm, hello.exe, hel-
lo.map,
 apis+pcms+slibca;

Microsoft (R) Segmented-Executable Linker  Version 5.10
Copyright (C) Microsoft Corp 1984-1990.  All rights reserved.
```

When the MS-DOS prompt appears, all the steps for building HELLO.EXE have been completed.

MAKEFILE.1 may be used as a pattern for makefiles which build other applications. Just change the OBJLIST macro and target .EXE file name appropriately. For example, to build a PCM application called **myapp.exe** from the sources **myapp1.c**, **myapp2.c**, and **myapp3.c** use:

```
OBJLIST=myapp1.obj myapp2.obj myapp3.obj

  .   .   .

myapp.exe : $(OBJLIST)
```

Note

As the total number of characters in the OBJLIST macro definition increases, the LINK command line issued by NMAKE or NMK will eventually exceed the MS-DOS command length limit. When this happens, linker errors will occur. The remedy is to use a linker response file for long command input. See the Microsoft LINK documentation.

For more information on makefiles, NMAKE and NMK, see the Microsoft C documentation.

Chapter 4 Using PCM Resources

The GE Fanuc Series 90™ Programmable Coprocessor Module (PCM) family provides a platform within Series 90 PLCs for C applications developed by OEMs and system integrators. This chapter is an overview of the resources provided by PCMs and PLC CPUs.

PCM Hardware Resources

Each PCM is equipped with 128 to 640K bytes of RAM, 256K bytes of EPROM (128K bytes of which is dedicated to system firmware), two high performance serial ports, a PLC backplane communication channel to the PLC CPU, three programmable timers, and three programmable light emitting diode (LED) indicators (two of which may be programmed by applications).

In addition to communication between the PCM and PLC CPU, the PLC backplane communication channel supports communication between two or more PCMs in the same PLC. Series 90-70 PCMs can also operate as VMEbus masters to read and write VMEbus memory in other PLC modules.

The VTOS Operating System

VTOS is a small, real-time, multitasking operating system which runs on the PCM family of products. It provides system services to C applications. VTOS is optimized for process control, communications, and operator interface applications on the Intel 80186 and 80188 processors.

VTOS provides these key features:

- A pre-emptive scheduler supports both priority-based and time-slice scheduling of application tasks.
- The majority of system services are implemented in assembly language to minimize execution times.
- Event flags, semaphores, shared memory, and asynchronous traps are provided for inter-task communication.
- A real-time clock provides up to 256 programmable timers with one millisecond resolution and a seven-week range.

- A device manager provides access to the serial ports; files stored in RAM, ROM, or the disk drives of an attached PC; and backplane access to Series 90-70 and 90-30 PLC CPUs as well as other PCMs in the same PLC. A consistent interface is provided for all devices, which is similar to asynchronous I/O under UNIX:
  - Each task has predefined standard input, output and error channels which can be redirected to any device;
  - Tasks can open channels to any PCM device;
  - I/O can proceed asynchronously to task execution;
- The VTOS memory manager and PCM battery-backed RAM allow user programs and data to be retained in memory through power outages.
- A fast runtime memory manager allocates memory blocks in as little as 50 microseconds.
- A command interpreter loads and runs user tasks and controls their execution environment.
- A batch file facility starts applications automatically when the PCM powers up or is reset.
- VTOS supports user programs in EPROM.

These services are built into the PCM firmware. A small library of interface functions provides access from application code.

The VTOS File System

Files in the PCM are stored in either RAM, EPROM, or EEPROM (in the PCM 301 only). Consequently, there are some important differences between VTOS files and files in a disk operating system:

1. Disk file systems are based on magnetic storage media, which have an inherent block structure based on disk tracks and sectors. VTOS files, however, are structured at the lowest level as sequential files of bytes, or stream files.

   PCM C developers may choose to impose their own block structure on the data in VTOS files. VTOS provides services for random access to files.

2. Data read and write operations on magnetic media are inherently slow. Disk file systems use buffering to minimize the impact on applications. When an application writes data to a file, the data is actually put into a file buffer in memory. Closing the file is often the only way to force the file system to move all the data to the disk and update the file directory with the correct file size.

   One result is that data may be lost when an application ‘‘hangs’’. Under MS-DOS, for example, recovering from a hung application often requires a warm boot (Ctrl-Alt-Delete reset). If the application opened a new output file but did not close it before hanging, the file size will be zero (0) after the warm boot.

   VTOS files are not buffered. Because read and write operations are performed directly on RAM or ROM, buffering would actually make them slower. Each write operation at the end of a file adds the new data and updates the file size. If the application should hang, all the data it wrote will be in the file.

The PCM Command Interpreter

The user interface to the PCM is a command interpreter which is conceptually similar to the MS-DOS command line interpreter or the Unix shell. The PCM command interpreter allows the user to download application programs and run them, and provides many other commands which are listed in appendix B, *PCM Commands*. The interpreter also supports batch files, which are described in appendix C, *Batch Files*. A special startup batch file named PCMEXEC.BAT can be used to run applications automatically on power-up or reset.

By default, the command interpreter uses PCM serial port 1 (COM1:) as its input and output device. However, it can be redirected to serial port 2 (COM2:) or the PLC backplane device (CPU:). It can communicate with any character mode device.

Accessing PLC Data From PCM Programs

Data from the PLC CPU is almost always an important part of PCM applications. There are four ways PCM programs can access PLC data:

1. The VTOS **`Open_dev`**, **`Read_dev`**, **`Write_dev`**, and **`Close_dev`** services;
2. PLC API services;
3. COMMREQ messages from PLC programs; and
4. Series 90-70 VME function blocks.

PCM applications can use any or all of these methods, except that VME function blocks are available only in Series 90-70 PCMs. The following sections provide an overview of each of these methods.

VTOS CPU: Device Services

The built-in VTOS device driver for the PC: device supports I/O operations between PCM applications and PLC data. PCM applications can open I/O channels to all PLC global data references. Each channel must be opened by calling the Open_dev function and specifying a device name of the form **"CPU:%**<*ref_letter*>**"**, where <*ref_letter*> is a single letter that specifies a PLC memory reference type.

PLC API Services

Series 90 PLCs provide a rich set of services which are accessible from PCMs. The PLC service request Application Program Interface (API) library provides convenient function calls to:

1. Open a PLC API session with the PLC CPU;
2. Determine PLC operational status;
3. Determine the PLC CPU hardware type and data sizes;
4. Obtain the PLC user program and configuration data checksums;
5. Read the I/O and PLC fault tables;
6. Check Series 90-70 PLCs for faulted racks, modules, Genius busses, and Genius devices;

7. Clear the I/O and PLC fault tables;
8. Read collections of mixed PLC data references;
9. Change the PLC access privilege level;
10. Read and write PLC data references;
11. Read and write Series 90-70 Program (%P) and Local (%L) data;
12. Read and set the PLC time-of-day clock; and
13. Start and stop PLC program execution.

For more information on PLC API services, see chapter 5, *PCM Libraries and Header Files.*

Communications Request (COMMREQ) Messages From PLC Programs

PLC programs can send messages to PCM programs with COMMREQ function blocks. Each COMMREQ message can include up to 128 words (256 bytes) of PLC data. COMMREQ data must be a contiguous block from a single, word-oriented, PLC reference type (%R, %IA, or %AQ in both Series 90-70 and Series 90-30 COMMREQs plus %P or %L in Series 90-70 COMMREQs only). Discrete PLC data types may not be transferred directly as COMMREQ data. However, they can be copied to a word-oriented type and then transferred by a COMMREQ.

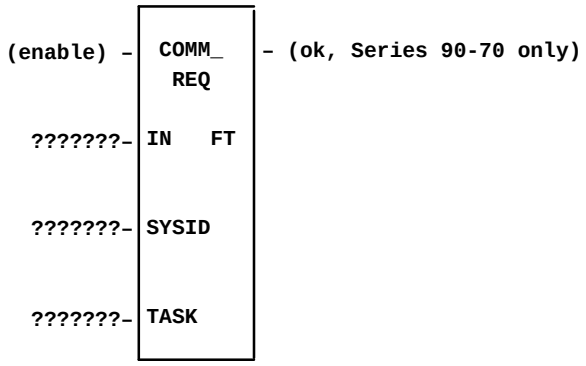
COMMREQ function blocks may be programmed for either WAIT mode or NOWAIT mode. In WAIT mode, the PLC CPU sends a COMMREQ message and waits for a reply from the target PCM before ladder program execution continues. In NOWAIT mode, ladder execution continues immediately after the COMMREQ message is sent.

Caution

NOWAIT mode should always be used, because WAIT mode COMMREQs can significantly degrade PLC sweep time. In addition, WAIT mode COMMREQs can cause the PLC watchdog timer to expire, halting PLC program execution.

Programming COMMREQ Function Blocks

COMMREQ function blocks have four inputs. Series 90-30 COMMREQs have one output, while Series 90-70 COMMREQs have two.



IN: This parameter specifies the PLC memory location where the COMMREQ command block begins; for example, %R00001. The COMMREQ command and data blocks must occupy contiguous areas within one of the word-oriented PLC data types listed above. The command block is described in the next section.

SYSID: This parameter species the rack and slot address of the target PCM. Logicmaster 90 software displays SYSID as a hexadecimal value. Its most significant byte must contain the rack number of the target PCM, and the least significant byte must contain the slot address. For example, the value 0102 hexadecimal specifies rack 1, slot 2. Note that Series 90-30 PCMs must be installed in rack zero.

If SYSID does not specify a rack / slot address where a PCM or other Series 90 module capable of receiving COMMREQs is installed, no COMMREQ will be sent when the function block is enabled, and the function block FT output will become active.

TASK: This parameter species the ‘‘task’’ or service point in the target PCM where the COMMREQ will be delivered. This value is **not** equivalent to the VTOS task number of the destination task. Instead, it is the numeric value specified in the device name string passed to a call by the VTOS **Open_dev** function:

```
word commreq_handle;
commreq_handle = Open_dev( “cpu:#<number>”, ...
```

where **commreq_handle** is a VTOS handle for the device I / O channel where COMMREQs will be received, and *<number>* is the service point value for that channel. Service point values must be in the range 4 through 120 decimal. Note that values outside this range are either invalid or reserved for use by VTOS.

A PCM task may open more than one service point for COMMREQ messages.

Caution

Logicmaster 90 software displays this parameter in hexadecimal format, while `Open_dev` expects service point values in device name strings to be specified in decimal format. The same *`value`* must be used for both; otherwise the COMMREQ message will not be delivered to the target task, and an Invalid Task fault will be posted to the PLC fault table.

The safest technique is to enter the COMMREQ TASK value in decimal format on the Logicmaster 90 input line. Before pressing the Enter key to accept the value, verify visually that is the same one used in the **`Open_dev`** device name.

OK and FT: The OK and FT (fault) outputs can provide power flow to optional logic to verify that the COMMREQ was sent successfully. Note that Series 90-30 COMMREQ function blocks have no OK output. OK and FT can have these states:

Enable	Error?	OK Output	FT Output
Active	No	TRUE	FALSE
Active	Yes	FALSE	TRUE
Not active	No execution	FALSE	FALSE

In NOWAIT mode, a COMMREQ function block with a valid SYSID always passes power flow to the OK output whenever it executes.

The FT output becomes active in NOWAIT mode if:

1. There is no PCM or other intelligent module in the rack and slot specified by the SYSID input.
2. The data length specified in the command block is zero or greater than128 words.

The COMMREQ Command and Data Blocks

The command block provides additional information about the COMMREQ message needed by the COMMREQ function block.

The address of the command block is provided to the IN input to the COMMREQ function. This address may be in any word-oriented PLC reference (%R, %AI or %AQ in both the Series 90-70 and Series 90-30 COMMREQ; %P or %L in the Series 90-70 COMMREQ only). The length of the command block is always 6 words. The COMMREQ data must immediately follow the command block, in the same reference table.

The command block has the following structure:

Data Block Length	Start address +0 (word 1)
Wait / No Wait Flag	Start address +1 (word 2)
Status Pointer Memory Type	Start address +2 (word 3)
Status Pointer Offset	Start address +3 (word 4)
Idle Timeout Value	Start address +4 (word 5)
Maximum Communication Time	Start address +5 (word 6)
Data Block	Start address +6 (word 7) through Start address +133 (word 134)

Information required for the command block can be placed in the designated memory area using the MOV or BLKMOV function block.

When entering information for the command block, refer to these definitions:

Data Block Length: This word contains the number of data words starting at address +6 (word 7) to the end of the data block, inclusive. The data block length ranges from 1 to 128 words.

Wait/Nowait Flag: This word selects whether or not the program should wait for the COMMREQ to be acknowledged by the PCM before the PLC sweep continues. This word should **always** be set to zero to select NOWAIT mode.

Status Pointer Memory Type: The two status pointer words specify a PLC memory location where the target PCM is expected to write a status word. Status Pointer Memory Type must contain a numeric word value that specifies the PLC memory reference type for the status word location. The table below shows the code for each reference type:

Status Pointer Memory Type:

For This Memory Type		Use This Value
%I	Discrete input table	16
%Q	Discrete output table	18
%R	Register memory	8
%AI	Analog input table	10
%AQ	Analog output table	12

The most significant byte of the word value at address +2 should contain zero.

Status Pointer Offset: The word at address +3 contains the zero–based offset for the status word location within the selected memory type. For example, %R00001 is at offset zero in the register table. %R00300 is at offset 299.

Idle Timeout Value: The idle timeout value is the maximum time the PLC CPU waits for the target PCM to acknowledge receipt of the COMMREQ. This value is ignored in NOWAIT mode.

Maximum Communication Time: The value at address +5 specifies the maximum time the PLC CPU waits for the target PCM to complete the COMMREQ. This time is also ignored in NOWAIT mode.

Data Block: The COMMREQ data block contains all the data which the PLC CPU will send to the target PCM with the COMMREQ message. The data size, in words, is specified by the **Data Block Length** value, described above.

Receiving COMMREQ Messages In a PCM Program

PCM C applications receive COMMREQ messages by calling **Open_dev** to open an I/O channel on the CPU: device for reading, and then calling **Read_dev** to copy each COMMREQ message to a program variable.

The following program fragment opens a channel using a service point it calculates by adding ten to its VTOS task number. Note that the VTOS device I/O operations in this example use WAIT mode I/O to receive NOWAIT COMMREQs. There is no connection between PLC CPU COMMREQ WAIT/NOWAIT modes and the notification mode used by VTOS I/O.

```
#include <vtos.h>
#include <cpu_data.h>
#include <stdlib.h>

comreq_msg  msg;
char        dev_name[] = "cpu:#00";
word        task_no;
word        commreq_handle;
word        read_size;
word        commreq_data_buffer[128];
word        commreq_data_size = 0;
word*       commreq_data_ptr = NULL;

task_no = Get_task_id();
        /* insert task number + 10 into device name string */
itoa( task_no + 10, dev_name + 5, 10 );
        /* open an I/O channel to read COMMREQ messages */
commreq_handle = Open_dev( dev_name, READ_MODE, WAIT, task_no);
        /* loop forever */
for (;;) {
        /* clear the COMMREQ data size and pointer values */
    commreq_data_size = 0;
    commreq_data_ptr = NULL;
       /* read a COMMREQ */
    read_size = Read_dev( commreq_handle,
                          msg,
                          COMMREQ_MSG_SIZE,
                          WAIT,
                          task_no );
       /* if a complete COMMREQ was read, extract the data */
    if (read_size = COMMREQ_MSG_SIZE) {
       /* test the COMMREQ message type byte */
       if (msg.header.msg_type & 0x40) {
       /* COMMREQ data is in the message; set the data size and pointer */
          commreq_data_size = 6;
          commreq_data_ptr = msg.data.short_c.data;
       } else {
       /* there is a separate COMMREQ data buffer; read it */
          read_size = Read_dev( commreq_handle,
                                commreq_data_buffer,
                                msg.data.long_c.data_size,
                                WAIT,
                                task_no );
          if (read_size == msg.data.long_c.data_size) {
       /* all the data was read; set the data size and pointer */
                commreq_data_size = read_size/2;
                commreq_data_ptr = commreq_data_buffer;
          }
       }
    }
}
```

The example opens a channel to read COMMREQ messages and then enters a non-terminating loop to wait for COMMREQs. If a COMMREQ and its data are read successfully, **commreq_data_size** contains the number of data words, and **commreq_data_ptr** contains the address of an array of words containing the data. If an error occurred, **commreq_data_size** contains zero.

Note that there are two formats for COMMREQ messages, depending on whether the data size is 6 or fewer words (the short format) or more than 6 words (the long format). Accordingly, PCMC\INCLUDE\CPU_DATA.H contains a C union type definition, **comreq_msg**, for COMMREQs. Both formats begin with a 16-byte header structure. The header contains a **msg_type** member which can be tested to determine the format of each COMMREQ message. COMMREQ messages with the **0x40** bit set contain 6 or fewer data words. If the bit is not set, the COMMREQ has a separate data buffer, and a second **Read_dev** call is used to get the data.

Note also that the COMMREQ message does not specify the data size when there are six or fewer data words. If the data size can vary and must be known, the data should specify its own size with a value in the first data word.

Responding to COMMREQs

The next program fragment illustrates the preferred method for returning a COMMREQ acknowledgement to the PLC CPU. The status pointer type and offset values specified in the COMMREQ command block are included in the COMMREQ message. This example shows how to extract the status address from the message and write a status value to it.

```
/*
 * #include directives and data declarations from the previous example
 * are not repeated here
 */
special_dev_8_type  status_addr;
word                status_hndl;
word                commreq_status = 1;

        /* open a channel for writing to the PLC status location */
        /* the data type and offset are not important */
status_hndl = Open_dev( "CPU:%R1", WRITE_MODE, WAIT, task_no );
        /* read a COMMREQ message as in example above (not repeated here) */
        /* test the COMMREQ message type */
if (msg.header.msg_type & 0x40) {
        /* COMMREQ data is in the message; get the status type and offset */
    status_addr.type    = msg.data.short_c.status_type;
    status_addr.offset  = msg.data.short_c.status_offset;
} else {
        /* separate COMMREQ data buffer; get the status type and offset */
    status_addr.type    = msg.data.long_c.status_type;
    status_addr.offset  = msg.data.long_c.status_offset;
}
        /* change the PLC data location of the status_handle channel */
Special_dev( status_handle, 8, &status_addr, 0, WAIT, task_no );
        /* write a status value to the new location */
Write_dev( status_handle, &commreq_status, 2, WAIT, task_no );
```

The VTOS **Special_dev** function permits changing the PLC reference data type and offset for a channel opened on the CPU:% device. This capability allows a channel to be opened to a dummy reference address. The channel is then switched to the actual status address for each COMMREQ.

Regulating the Timing of COMMREQ Messages

There are two COMMREQ timing issues: the time when the first COMMREQ for a PCM task arrives, relative to task initialization; and the speed with which repeated COMMREQs arrive.

The target PCM will reject a COMMREQ that is addressed to a valid service point if a COMMREQ is sent before the PCM program has opened the service point. PLC ladder programs must provide some mechanism for preventing COMMREQs from being sent before the target PCM application is ready to receive them. In particular, a PLC power cycle or brownout causes all the PCMs in the PLC to re-initialize themselves. The first COMMREQ to any PCM must be delayed until the PCM has finished initialization, VTOS has started the application tasks, and the application has opened the target service point(s).

The simplest method for preventing a PLC program from sending COMMREQs before the target PCM is ready to receive them is to start a timer on the first scan of the PLC program. When a fixed time delay expires, program logic enables the COMMREQ function blocks. The recommended delay is five seconds.

The PLC program folders \PCMC\EXAMPLES\DEMO_3T\PLC_30 and \PCMC\EXAMPLES\DEMO_3T\PLC_70, installed with the PCM C toolkit, contain PLC programs with timers to prevent COMMREQs during the first five seconds of program execution.

The other COMMREQ timing issue concerns the speed at which COMMREQ messages arrive. VTOS has a queue for messages which arrive from the PLC CPU. When a COMMREQ message arrives, it is stored in this queue until the PCM application makes a **Read_dev** function call to get it. When COMMREQs arrive more rapidly than **Read_dev** calls are made, the queue eventually overflows. When overflow occurs, no more COMMREQ messages can be received until a message slot in the queue is freed by a **Read_dev** call. Until then, new messages are lost. The PCM posts a fault to the PLC fault table whenever a message is lost.

Queue overflow can be avoided by designing the PLC program so that no more than two COMMREQ messages are outstanding to each PCM in the PLC at any time. The PLC programs in folders \PCMC\EXAMPLES\DEMO_3T\PLC_30 and \PCMC\EXAMPLES\DEMO_3T\PLC_70 also contain logic which waits for the target PCM to acknowledge each COMMREQ before the next one is sent.

Using Series 90-70 VME Function Blocks

Series 90-70 PLC ladder programs can also communicate with the PCM using the VME Read (VMERD) and VME Write (VMEWRT) functions. These functions are not available for Series 90-30 PLCs.

VMERD, VMEWRT, and other associated functions treat the PCM as a standard VMEbus module. Data is moved to and from the PCM's VMEbus dual port RAM.

VME functions usually execute faster than the equivalent COMMREQ for the same data transfer. These functions can also be useful in situations when the PLC System Communications Window must be severely shortened or eliminated.

However, VME functions lack many of the advantages of COMMREQs, including:

- Guaranteed data coherency.
- Automatic protection against simultaneous access to the same data location by the PCM and PLC CPU.
- Fault reporting of some user programming errors, such as an invalid task or the wrong rack / slot.
- No requirement for user knowledge or manipulation of dual port addresses.

Most applications should use COMMREQ function blocks to transfer data between the ladder program and the PCM. VME functions should be used only when timing constraints or other factors dictate their use.

VME Function Blocks for Communicating with the PCM

A group of PLC functions blocks is available in Logicmaster 90 software to allow a Series 90-70 PLC CPU to communicate with VMEbus modules, including the PCM. These functions include:

- VME Read (VMERD).
- VME Write (VMEWRT).
- VME Read / Modify / Write (VMERMW).
- VME Test and Set (VMETS).

Each of these function blocks is discussed in detail later in this section.

Some Rules for VME Bus Operations in Series 90-70 PLCs

VMEbus block move transfers are not supported by Series 90-70 PLCs.

Do not install a PCM, or any other GE Fanuc Series 90-70 module, in a standard VMEbus rack. Series 90-70 modules must be installed only in Series 90-70 PLC racks.

For more information about VME in the Series 90-70 PCM, refer to the *Series 90-70 Programmable Controller User's Guide to the Integration of Third Party VME Modules*, GFK-0448.

General VME Information for the PCM

When a PCM is the target module for VME functions, it should be configured with the Logicmaster 90 configuration software in the same way it would be for non-VME functions. The PCM should not be configured as a foreign VME module.

Addresses on the Series 90-70 VMEbus consist of two parts, an address modifier (AM) code and a 24 bit address. The AM code consists of 6 bits and is used to select the target Series 90-70 rack and the type of VME access (that is, the number of address bits used). The AM code for a PCM is 39 hexadecimal. It specifies the *Standard Nonprivileged* access type.

VME bus addresses for PCM modules used as VME function block targets depend on the rack and slot location of the PCM. The PCM must be addressed in the range allocated to the rack and slot where it is located. Address allocations for PCMs are provided in the following table.

Table 4-1. GE Fanuc PCM Module Address Allocation

Rack Number	Slot Number							
	2	3	4	5	6	7	8	9
0	000000H to 07FFFH	020000H to 027FFFH	040000H to 047FFFH	060000H to 067FFFH	080000H to 087FFFH	0A0000H to 0A7FFFH	0C0000H to 0C7FFFH	0E0000H to 0E7FFFH
0	100000H through 7FFFFFH user-defined for rack 0 only.							
1	E00000H to E07FFFH	E20000H to E27FFFH	E40000H to E47FFFH	E60000H to E67FFFH	E80000H to E87FFFH	EA0000H to EA7FFFH	EC0000H to EC7FFFH	EE0000H to EE7FFFH
2	D00000H to D07FFFH	D20000H to D27FFFH	D40000H to D47FFFH	D60000H to D67FFFH	D80000H to D87FFFH	DA0000H to DA7FFFH	DC0000H to DC7FFFH	DE0000H to DE7FFFH
3	C00000H to C07FFFH	C20000H to C27FFFH	C40000H to C47FFFH	C60000H to C67FFFH	C80000H to C87FFFH	CA0000H to CA7FFFH	CC0000H to CC7FFFH	CE0000H to CE7FFFH
4	B00000H to B07FFFH	B20000H to B27FFFH	B40000H to B47FFFH	B60000H to B67FFFH	B80000H to B87FFFH	BA0000H to BA7FFFH	BC0000H to BC7FFFH	BE0000H to BE7FFFH
5	A00000H to A07FFFH	A20000H to A27FFFH	A40000H to A47FFFH	A60000H to A67FFFH	A80000H to A87FFFH	AA0000H to AA7FFFH	AC0000H to AC7FFFH	AE0000H to AE7FFFH
6	900000H to 907FFFH	920000H to 927FFFH	940000H to 947FFFH	960000H to 967FFFH	980000H to 987FFFH	9A0000H to 9A7FFFH	9C0000H to 9C7FFFH	9E0000H to 9E7FFFH
7	800000H to 807FFFH	820000H to 827FFFH	840000H to 847FFFH	860000H to 867FFFH	880000H to 887FFFH	8A0000H to 8A7FFFH	8C0000H to 8C7FFFH	8E0000H to 8E7FFFH

In PCM address space, VMEbus memory is located in the range 0xA000:0x0000 to 0xA000:0x7FFF, regardless of the rack / slot location where the PCM is installed.

The Series 90-70 VMEbus data path is 16 bits wide. All Series 90-70 modules support 16 bit data access from the VMEbus. When more than one byte of data will be transferred, the WORD data type should be specified for VME functions. WORD transfers move one word per VME bus cycle, but BYTE transfers require two bus cycles to move a word.

PCM Dual Port RAM Available for Applications

The PCM system software uses a large part of the first 4000 hexadecimal bytes of the PCM VMEbus dual port RAM. In addition, some PLC API library services require VMEbus RAM.

Caution

Addresses within the first 4000 hexadecimal bytes of PCM VMEbus memory should never be used as target addresses for VME functions. Use only addresses at or above offset 4000 hexadecimal.

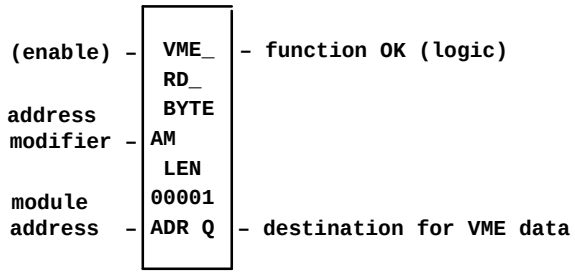
Future PCM enhancements are likely to use VMEbus memory above the first 4000 hexadecimal bytes. Applications should use the highest possible address for VME communication.

PCM C applications which use one or more blocks of VMEbus memory should reserve them by calling the VTOS function `Reserve_dp_buff`. This call should be made before any calls to `api_initialize`. The return value from the `Reserve_dp_buff` call should be tested to assure that the requested block of VME dual port memory is available for the application.

VME Read Function

The VMERD function can be used to read data from the dual port RAM of a Series 90-70 PCM to the PLC CPU. This function should be executed before the data is needed in the PLC ladder program.

The format of the VMERD function block is:



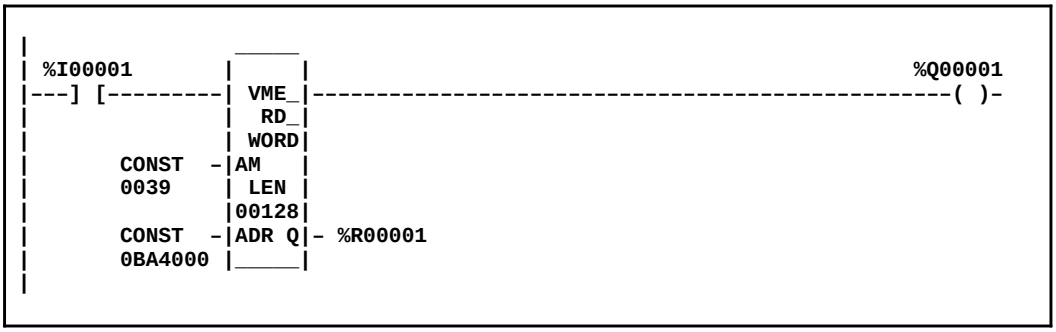
Parameter	Description
Enable	Power flow input that, when TRUE, enables the execution of the function.
Type	Function type, either BYTE or WORD, to select the corresponding type of VME bus access to be performed. WORD accesses transfer 16 bits of data on each VMEbus cycle, while BYTE accesses transfer just 8 data bits per buscycle.
LEN	An internal parameter that, depending on the function type, specifies the number of bytes or words to be transferred.
AddressModifier	A hexadecimal word value that specifies both the rack where the target PCM is installed and the VMEbus access mode to be performed.
ModuleAddress	A double word specifying the hexadecimal address where the first word or byte is read from the VME bus. It may be a constant or the reference address of the first (least significant) word of two words containing the module address. The address is based on the rack and slot where the PCM is located. (Refer to “Address Allocation by Rack and Slot” in this section.)
OK	Power flow output that is TRUE when the function is enabled and completessuccessfully.
Q	Specifies the first PLC user reference location into which the data read from the PCM is to be stored.

When the VMERD function receives power flow through its ENABLE input, the function accesses the PCM at the specified address ADR and copies LEN data units (words or bytes) from the PCM to PLC locations beginning at the output parameter Q. When the operation is successfully completed, the VMERD function passes power to the right through the OK output.

For information on PCM module addressing using addresses and address modifier codes, refer to "General VME Information for the PCM," presented earlier in this section.

Example VMERD Function

In this example, 128 words (256 bytes) of data are read from a PCM in rack 4, slot 7 into registers %R00001 through %R00128 whenever enabling input %I00001 is TRUE. Unless an error occurs while reading the data, output %Q00001 is set to TRUE.



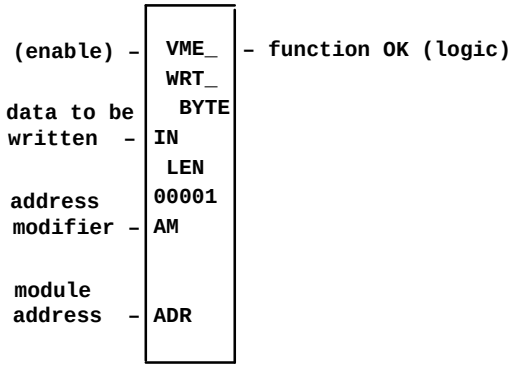
In Series 90-70 PCMs, VME dual port memory occupies 32K bytes. In PCM address space, VME memory begins at address 0xA0000:0x0000, regardless of the rack and slot where the PCM is installed. In this example, the VME bus address 0BA7000 hexadecimal corresponds to the PCM internal address 0xA000:0x7000.

There are several ways for PCM C programs to move data to this address in VMEbus dual port RAM. One of the simplest is to use the standard C library **`memcpy`** function.

VME Write Function

The VMEWRT function can be used to write data from a Series 90-70 CPU to the VME dual port RAM of the PCM. Locate the function block at a place in the program where the output data is ready to send.

The format of the VMEWRT function block is:



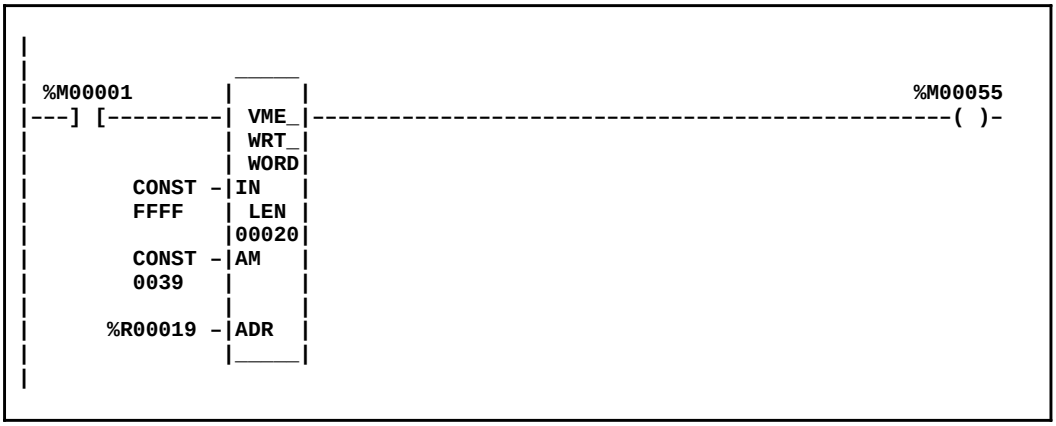
Parameter	Description
Enable	Power flow input that, when TRUE, enables the execution of the function.
Type	Function type, either BYTE or WORD, to select the corresponding type of VME bus access to be performed. WORD accesses transfer 16 bits of data on each VMEbus cycle, while BYTE accesses transfer just 8 data bits per buscycle.
LEN	An internal parameter that, depending on the function type, specifies the number of bytes or words to be transferred.
IN	Specifies the first PLC user reference location where the data to be written to the PCM is stored. This parameter may be a constant, in which case the constant value is written to all VME addresses covered by the function's length.
AddressModifier	A hexadecimal word value that specifies both the rack where the target PCM is installed and the VMEbus access mode to be performed.
ModuleAddress	A double word specifying the hexadecimal address where the first word or byte is read from the VME bus. It may be a constant or the reference address of the first (least significant) word of two words containing the module address. The address is based on the rack and slot where the PCM is located. (Refer to "Address Allocation by Rack and Slot" in this section.)
OK	Power flow output that is TRUE when the function is enabled and completessuccessfully.

When the VMEWRT function receives power flow through its enable input, LEN data units (words or bytes) from the PLC locations beginning at the input parameter IN are written to the PCM at the specified address ADR. When the operation is successfully completed, the VMEWRT function passes power to the right through the OK output.

For information on PCM module addressing using address and address modifier codes, refer to "General VME Information for the PCM," presented earlier in this section.

Example VMEWRT Function

In the following example, the hexadecimal value FFFF is written to each of 20 words on the PCM during every sweep when enabling input %M00001 is TRUE. The starting (lowest) PCM address is specified by the contents of %R00019 (low word) and %R00020 (high word). Unless an error occurs while writing the data, internal coil %M00055 is set to TRUE.

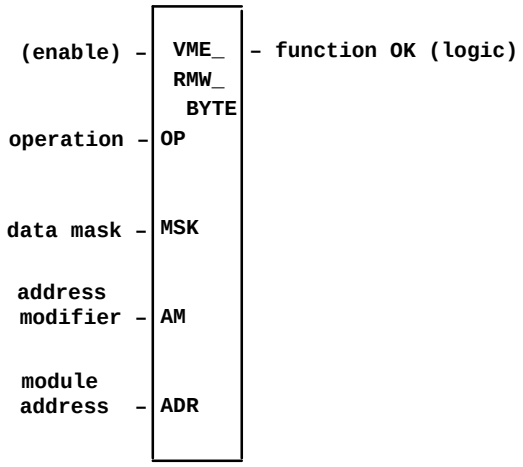


The PCM must be located in the rack and slot corresponding to the address contained in %R00019 and %R00020. The PCM C application would read this data from the PCM VMEbus dual port RAM by using, for example, a **`memcpy`** function call.

VME Read/Modify/Write Function

The VMERMW function can be used to update a data element in the dual port RAM of the Series 90-70 PCM. Once the sequence of operations begins, the PCM will not be able to access the data until the entire sequence has completed.

The format of the VMERMW function block is:



Parameter	Description
Enable	Power flow input that, when TRUE, enables the execution of the function.
Type	Function type, either BYTE or WORD, to select the corresponding type of VME bus access to be performed. WORD accesses transfer 16 bits of data on each VMEbus cycle, while BYTE accesses transfer just 8 data bits per bus cycle.
Operation	A constant which specifies whether an AND or OR function is to be used to combine the data and the mask. 0 specifies AND; 1 specifies OR.
Data Mask	A word value containing a mask to be ANDed or ORed with the data read from the bus. If Type is BYTE, only the least significant 8 bits of the mask are used.
Address Modifier	A hexadecimal word value that specifies both the rack where the target PCM is installed and the VMEbus access mode to be performed.
Module Address	A double word specifying the hexadecimal address of the word or byte to be accessed. It may be a constant or the reference address of the first (least significant) word of two words containing the module address. The address is based on the rack and slot where the PCM is located. (Refer to "Address Allocation by Rack and Slot" in this section.)
OK	Power flow output that is TRUE when the function is enabled and completes successfully.

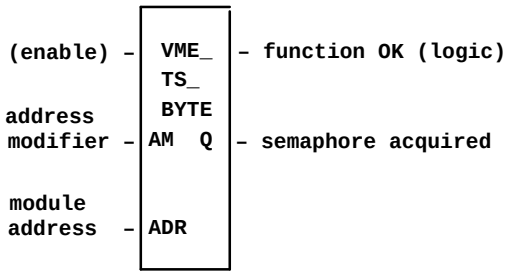
When the VMERMW function receives power flow through its enable input, the function reads a word or byte of data from the module at the specified address (ADR) and address modifier (AM). This byte or word of data is combined (AND / OR) with the data mask (MSK). Selection of AND or OR is made using the input OP. If byte data is specified, only the lower 8 bits of MSK are used. The result is then written back to the same VME address from which it was read. When the operation is successfully completed, the VMERMW function passes power to the right through the OK output.

For information on PCM module addressing using address and address modifier codes, refer to "General VME Information for the PCM," presented earlier in this section.

VME Test and Set Function

The VMETS function can be used to handle semaphores located in the VMEbus dual port RAM of a Series 90-70 PCM. The VMETS function exchanges a boolean TRUE (1) for the value currently at the semaphore location. If that value already was TRUE, then the VMETS function does not acquire the semaphore. If the existing value was FALSE, the semaphore is set and the VMETS function block has acquired control of the semaphore as well as the memory area it controls. The semaphore is cleared and control relinquished by using the VMEWRT function to write FALSE (0) to the semaphore location.

The format of the VMETS function block is:



Parameter	Description
Enable	Power flow input that, when TRUE, enables the execution of the function.
Type	Function type, either BYTE or WORD, to select the corresponding type of VME bus access to be performed. WORD accesses transfer 16 bits of data on each VMEbus cycle, while BYTE accesses transfer just 8 data bits per buscycle.
AddressModifier	A hexadecimal word value that specifies both the rack where the target PCM is installed and the VMEbus access mode to be performed.
ModuleAddress	A double word specifying the hexadecimal address of the first word or byte to be accessed. It may be a constant or the reference address of the first (least significant) word of two words containing the module address. The address is based on the rack and slot where the PCM is located. (Refer to "Address Allocation by Rack and Slot" in this section.)
OK	Power flow output that is TRUE when the function is enabled and completessuccessfully.
Q	Set to TRUE if the semaphore was acquired. Set to FALSE if the semaphore was not available, i.e., was owned by another task.

When the VMETS function receives power flow, a boolean TRUE is exchanged with the data at the address specified by ADR using the address mode specified by AM. The VMETS function activates the Q output if the semaphore was available and acquired by the function. When the operation is successfully completed, the VMETS function passes power to the right through the OK output.

For more information on Series 90-70 PLC programming, refer to the *Logicmaster 90-70 Programming Software User's Manual*, GFK-0263, and the *Series 90-70 Programmable Controller Reference Manual*, GFK-0265. For more information about Series 90-70 VME bus applications, refer to the *Series 90-70 Programmable Controller User's Guide to the Integration of Third Party VME Modules*, GFK-0448.

C Program Access to PCM Dual Port RAM

VMEbus dual port RAM occupies the address range 0xA000:0x0000 through 0xA000:0x7FFF in the current hardware revision of the Series 90-70 PCM. VTOS and the PLC API library use a part of this memory; the portion they use is at the low end of the address range.

When VME function blocks are used for data PCM transfers, both the PLC and PCM programs must know the location of a block of VMEbus memory. The application designer usually chooses a location for this memory block before the programs are written. However, it is possible for other PCM code to try to use the same memory block. It is important for all PCM code which uses VMEbus memory to allocate or reserve it through the VTOS **`Get_dp_buff`** or **`Reserve_dp_buff`**, respectively. If these functions are used, VTOS will prevent VMEbus memory conflicts.

This example shows how to place a memory block for VME data transfers at the top end of VMEbus dual port RAM, reserve it, and then free it when it is no longer needed.

The example assumes that the PLC CPU will use a VMEWRT function block to transfer data to the PCM, and that the first data word is used as a lock to control access to the data.

```
#include <vtos.h>
#include <dos.h>

#define VME_SIZE    (4 * 1024)
#define VME_LIMIT   (32 * 1024)
#define VME_OFFSET  (VME_LIMIT – VME_SIZE)

word       vme_available;
void far*  vme_ptr;
char       local_buff[VME_SIZE];

FP_SEG(vme_ptr) = 0xA000;
FP_OFF(vme_ptr) = VME_OFFSET;

vme_available = (Reserve_dp_buff( vme_ptr, VME_SIZE ) == SUCCESS);

if (vme_available) {
    _disable();
    while (*vme_ptr == 1) {
       _enable();
       Wait_time( MS_COUNT_MODE, 0, 5 );
       _disable();
    }
    *vme_ptr = 1;
    _enable();
    memcpy( local_buff, vme_ptr, VME_SIZE );
    *vme_ptr = 0;
}

Return_dp_buff( vme_ptr );
```

The Microsoft C header file DOS.H is included because it contains declarations of the functions **_disable** and **_enable**, and definitions for the macros FP_SEG and FP_OFF. These macros provide a simple method for assigning fixed addresses to far pointers.

This example uses a 4K byte memory block. The macro definitions VME_LIMIT and VME_OFFSET place it in the last 4K bytes of VMEbus memory. The segment and offset values for the block are assigned to a far pointer, **vme_ptr**.

The memory block is reserved by passing its start address and size to **Reserve_dp_buff**. If the call returns SUCCESS, **vme_avail** is set to one; otherwise, **vme_avail** is set to zero.

If the block was reserved successfully, the code tests the lock word in VMEbus memory. If the PLC CPU has control of the memory block, the code waits five milliseconds and tests the lock again. A VMEWRT WORD transfer of 4K data bytes takes about five milliseconds for a Series 90-70 Model 771 CPU. Note the **_disable** and **_enable** function calls. They disable hardware interrupts while the code acquires control of the lock byte. Without these calls, the task which executes this code could be pre-empted after it tested the lock word but before it could be changed. Interrupts must be enabled when **Wait_time** is called.

After the memory block is acquired, the data in it is copied to the array **local_buf** and the lock byte is unlocked. Finally, the memory block is freed by calling **Return_dp_buff**

Chapter 5 PCM Libraries and Header Files

This chapter describes how the libraries and header files provided with the PCM C toolkit are used to access PCM resources from C programs.

PCM Libraries

Two sets of libraries are furnished with the PCM C toolkit. Services provided by the PCM's VTOS operating system are accessed through the library files PCMS.LIB, PCMM.LIB, and PCML.LIB for the small, medium, and large memory models, respectively. PLC CPU services are provided by the PLC application program interface (PLC API) library files APIS.LIB, APIM.LIB, and APIL.LIB for the small, medium, and large memory models, respectively. The following sections describe VTOS and PLC API services.

VTOS Interface

VTOS services are provided as system service function calls and global data. Some of the services use predefined VTOS data types. The function calls, global variables, and data types are all defined in the C header file VTOS.H.

Data types used by the PLC CPU which are returned to PCM applications or sent to the CPU by VTOS device services are defined in CPU_DATA.H.

VTOS Services By Category

This section summarizes VTOS services by grouping them in categories of related services. For full details on all VTOS services, refer to the *PCM C Function Library Reference Manual*, GFK-0772.

Table 5-1. Task Management Functions

Function Name	Purpose
Get_task_id	Returns the task ID value of the calling task.
Init_task	Executes a VTOS device driver as a task.
Process _env	Starts a PCM task using a saved environment block.
Resume_task	Allows a task to execute.
Set_std_device	Sets a standard I / O channel for a task.
Suspend_task	Prevents a task from executing.
Terminate_task	Kills a task permanently and frees its resources.
Test_task	Returns the set of active tasks.
Wait_task	Waits for a specified task to terminate.

PCM applications, including these using multiple tasks, should be started from PCMEXEC.BAT files. It is possible (but **not** recommended) to start one application task from PCMEXEC.BAT and then start the others from the first by calling **Init_task** or **Process_env**. A task's ID value is required by many VTOS services and may be obtained by calling **Get_task_id**. Task execution can be temporarily stopped by **Suspend_task** and then started again by **Resume_task**. **Test_task** is used to determine which task numbers are active, and **Wait_task** permits a task to wait until a lower priority task terminates (for example, by exiting its **main** function). **Set_std_device** reassigns the I/O channels assigned to the predefined STDIN, STDOUT, and STDERR devices for a task, and **Terminate_task** permits a task to terminate its own execution or that of another task. Note that **Terminate_task** is called automatically when a task returns from its **main** function.

Event Flag Functions

Table 5-2. Event Flag Functions

Function Name	Purpose
Iset_ef	Sets one or more local event flags from an interrupt or communication timer service routine.
Iset_gef	Sets one or more global event flags from an interrupt or communication timer service routine.
Reset_ef	Resets one or more local event flags.
Reset_gef	Resets one or more global event flags.
Set_ef	Sets one or more local event flags.
Set_gef	Sets one or more global event flags.
Test_ef	Tests one or more local event flags.
Test_gef	Tests one or more global event flags.
Wait_ef	Waits for one or more local event flags to be set.
Wait_gef	Waits for one or more global event flags to be set.

Each PCM task has 16 local event flags which it can use to determine when external events occur. There are also 16 global event flags shared by all PCM tasks. A task can test its own local event flags, to determine whether one or more of them is set, using **Test_ef**. A task can also clear one or more of its own local event flags using **Reset_ef**. Any task can test or clear one or more global event flags by using **Test_gef** or **Reset_gef**, respectively.

Any task may set the global event flags as well as local event flags for any task. Global event flags should be set from communication timer timeout functions (see **Start_com_timer** in the *PCM C Function Library Reference Manual*, GFK-0772) or device drivers by calling **Iset_gef**. All other functions can set global event flags by calling **Set_gef**. Similarly, local event flags should be set from communication timer timeout functions or device drivers by calling **Iset_ef**, while other functions can set them by calling **Set_ef**.

A task can wait for one or more global or local event flags to be set by external events by calling **Wait_gef** or **Wait_ef**, respectively. Event flags should be reset before a task waits for them; otherwise, **Wait_gef** or **Wait_ef** will return immediately if one of the specified flags happens to be set.

Asynchronous Trap Functions

Table 5-3. Asynchronous Trap Functions

Function Name	Purpose
Disable_asts	Prevents the calling task from processing ASTs.
Enable_asts	Permits the calling task to process ASTs.
Post_ast	Sends an asynchronous trap to a specified task.
Wait_ast	Suspends execution of the calling task until an AST is received.

Asynchronous traps (ASTs) may be set for timer and device I/O events. See "Timer Functions and Device I/O Functions," below. A task may suspend execution and wait for one or more traps to spring by calling **Wait_ast**. When the event occurs, an AST handler function which was previously specified for that event is executed. After the AST function returns, the **Wait_ast** function call which suspended the task also returns, and the task resumes normal execution.

Tasks may prevent ASTs from being processed by calling **Disable_asts**, and may resume AST processing by calling **Enable_asts**. A task may send an AST to itself or a different task by calling **Post_ast**.

Semaphore Functions

Table 5-4. Semaphore Functions

Function Name	Purpose
Block_sem	Checks whether a semaphore is open; wait if not.
Link_sem	Links the calling task to a named semaphore; create one if it is not found. If the semaphore already exists and is controlled by another task, the calling task waits.
Unblock_sem	Releases a semaphore, and activates the first waiting task.
Unlink_sem	Unlinks the calling task from a semaphore.

Two or more tasks can share memory modules (but **not** I/O channels) by using named semaphores. A task may create a new named semaphore or use an existing one by calling **Link_sem**. The task calls **Block_sem** before using the resource and then calls **Unblock_sem** when it is finished. If the resource is available (that is, the semaphore is "open"), execution proceeds immediately. However, if another task is already using the resource (the semaphore is "closed"), execution is suspended until the resource is available again.

Note that **Link_sem** leaves the semaphore closed. **Unblock_sem** must be called after the **Link_sem** call. Typically, the controlled resource is accessed between calls to **Link_sem** and **Unblock_sem**.

An unused semaphore can be freed by calling **Unlink_sem**, but this is rarely necessary. One possible application might be for a semaphore used only during initialization when PCM memory is tight.

Time-of-Day Clock Functions

Table 5-5. Time-of-Day Clock Functions

Function Name	Purpose
Elapse	Returns a count of milliseconds since the last time its count was reset.
Get_date	Returns the current date.
Get_time	Returns the current time of day.

Get_date and **Get_time** return the current date and time, respectively, from the PCM time-of-day clock. The PCM clock is synchronized with the PLC time-of-day clock once per second. The PLC time-of-day clock can be read directly by using **read_date**, **read_time**, or **read_timedate**, described below.

Elapse returns a count of milliseconds since the last time it was reset by passing zero as its parameter. The **Elapse** count is unaffected by PCM time-of-day clock synchronization.

Caution

Do <u>not</u> use Get_time to calculate the time interval between two events. The value returned by Get_time is affected by synchronization of the PCM time-of-day clock with the PLC CPU. If the PCM clock is re-synchronized with the PLC CPU between two calls to Get_time, the calculated time interval will be incorrect.

<u>Always</u> use Elapse to determine time intervals. PCM clock synchronization has no effect on Elapse.

Timer Functions

Table 5-6. Timer Functions

Function Name	Purpose
Cancel_timer	Stops a timer and undefines it.
Start_timer	Defines a timer and starts it counting from zero.
Wait_time	Suspends execution of the calling task for the specified time.

Up to 32 general purpose timers may be used by PCM applications. Timers are started by calling **Start_timer**, and are programmed to expire after either a specified number of days, hours, minutes, seconds, and milliseconds, or a specified long integer number of milliseconds in the future. Timers may be programed to restart automatically when they expire or for "one shot" operation. When the timer expires, a specified task (usually the task which started the timer) is notified either by a local event flag or an asynchronous trap. A timer which is running can be stopped by calling **Cancel_timer**.

A task may suspend its own execution for a specified time interval by calling **Wait_time**. When the time expires, the **Wait_time** call returns.

Communication Timer Functions

Table 5-7. Communication Timer Functions

Function Name	Purpose
Alloc_com_timer	Allocates a communication timer to the calling task.
Cancel_com_timer	Stops a communication timer.
Dealloc_com_timer	De-allocates a communication timer.
Start_com_timer	Starts a previously allocated communication timer.

Four communication timers are available in the PCM. They require far less execution overhead than general purpose timers, and are recommended when short time intervals are required. A task must call **Alloc_com_timer** to reserve a communication timer before it can be used. Communication timers are started by calling **Start_com_timer**. The time interval is specified as milliseconds, and is limited to 65.535 seconds or less. When the timer expires, a timeout function, which was specified as a **Start_com_timer** parameter, is called.

A running communication timer can be stopped by calling **Cancel_com_timer**. Unused communication timers are freed by calling **Dealloc_com_timer**.

Memory Management Functions

Table 5-8. Memory Management Functions

Function Name	Purpose
Get_best_buff	Allocates memory from the smallest free memory block which is at least as large as the requested size.
Get_buff	Allocates memory from the first free memory block which is at least as large as the requested size.
Get_dp_buff	Allocates memory from free VMEbus dual ported RAM in a Series 90-70 PCM.
Get_mem_lim	Returns the starting address of a memory block reserved for application programs.
Max_avail_buff	Returns the size in bytes of the largest free memory block.
Max_avail_mem	Returns the total number of bytes in free memory.
Reserve_dp_buff	Reserves a specified block of VMEbus dual ported RAM in a Series 90-70 PCM.
Return_buff	Returns the specified memory buffer to the free memory pool.
Return_dp_buff	Returns the specified block of VMEbus dual ported RAM to the free memory pool in a Series 90-70 PCM.

Two functions are provided for allocating blocks of free memory in PCM RAM. When there are gaps in free memory, **Get_best_buff** searches the list of free blocks to find the smallest one which fits the requested size. **Get_buff** allocates a buffer from the first free block which is large enough. **Get_buff** is faster, but **Get_best_buff** is recommended for applications which use many temporary buffers because it minimizes free memory fragmentation. Note that the built-in I/O device drivers use temporary buffers heavily.

Note

The standard C library function **malloc** is redefined in PCMC\INCLUDE\MALLOC.H and PCMC\INCLUDE\STDLIB.H as **Get_buff**. You may wish to modify these header files so that malloc is redefined to be **Get_best_buff**.

A buffer which was allocated by either **Get_buff** or **Get_best_buff** may be deallocated by calling **Return_buff**. If the returned buffer is adjacent to one or two free memory blocks, they are consolidated. This is the PCM's only runtime "garbage collection" facility.

The total free memory size in bytes is returned by **Max_avail_mem**, and the largest free block size is returned by **Max_avail_buff**.

Applications can call **Get_mem_limit** to determine whether PCM memory has been partitioned to exclude some memory from VTOS by the command interpreter Y (Set Upper Memory Limit) command. A pointer to the start of the excluded partition is returned if there is one; otherwise, a NULL pointer is returned.

In Series 90-70 PCMs, a block of dual ported memory on the VMEbus can be allocated by calling **Get_dp_buff**. Applications can also reserve a specified region of VMEbus memory by calling **Reserve_dp_buff**. Applications which use VME dual ported memory should call one of these services to avoid memory conflicts with PLC API services and built-in backplane communication services. Unused VME dual ported memory is freed by calling **Return_dp_buff**.

Memory Module Functions

Table 5-9. Memory Module Functions

Function Name	Purpose
Get_mod	Returns the address of a named memory module.

A task may obtain the address of a named memory module by calling **Get_mod**. It returns the **far** address of the **mod_hdr** structure at the start of the memory module.

Device I/O Functions

Table 5-10. Device I/O Functions

Function Name	Purpose
Abort_dev	Aborts one or more I/O operations on a previously opened I/O channel.
Close_dev	Closes a previously opened I/O channel.
Devctl_dev	Performs a specified control operation on a named device.
Ioctl_dev	Performs a specified control operation on a previously opened I/O channel.
Open_dev	Opens a channel on a named I/O device.
Read_dev	Returns input data from a previously opened I/O channel.
Seek_dev	Positions the data pointer of a previously opened I/O channel to a specified location.
Special_dev	Performs a special operation on a previously opened I/O channel.
Write_dev	Sends output to a previously opened I/O channel..

The PCM supports I/O through named devices, and all devices use a common access model. Presently, these devices are available:

Device Name	Description
COM1:, COM2:	The PCM serial ports.
REM1:,REM2:	The PCM backplane remote devices.
CPU:<object name>[,<qualifiers>]	The PCM backplane device.
RAM:	The PCM RAM disk file system.
ROM:	The PCM 301 EEROM device file system.
PC:	The MS-DOS file system on an attached personal computer.
NULL:	A dummy device which does not support actual I/O.

For more information on specific PCM devices, see **Open_dev** in the *PCM C Function Library Reference Manual*, GFK-0772.

A channel must be opened on a device by calling **Open_dev** before any I/O operations may take place. Data is input from a device by calling **Read_dev** and output to a device by calling **Write_dev**. When I/O operations on a channel are completed, it may be closed by calling **Close_dev**.

The data pointer for an I/O channel may be set to a specified position by using **Seek_dev**.

The **Devctl_dev** function may be used to format the PCM 301 EEROM device; delete named files; return the names in a file directory; determine the unused file space remaining in the EEROM device; set or clear AST notification of received serial breaks; and set or clear the serial All Sent event flag.

Ioctl_dev can be called to determine whether a specified channel is a character or file-oriented channel, whether the channel has input data available (and if so, how much), whether the channel is ready for output data, and whether an ASCII ETX (Ctrl-C) character has been received; to purge the channel's input or output buffer; to control serial port Send Break, RTS, and DTR status; and check Break Detect status.

Special_dev is used to determine the size of a file accessed through a specified channel or set its maximum size, to specify passwords for PLC CPU data access, to set serial port communication parameters, to set the Series 90 PLC rack/slot destination address for backplane messages, to set files to read-only access mode, to set the memory type and starting offset for PLC CPU data access, and to set high priority mode for backplane messages.

Device I/O operations may be performed in WAIT, EVENT_NOTIFY, or AST_NOTIFY mode. In WAIT mode, the function call does not return until the specified operation completes. In EVENT_NOTIFY and AST_NOTIFY modes, the function call returns immediately, and the task is notified of completion of the I/O operation by a local event flag or AST, respectively. EVENT_NOTIFY and AST_NOTIFY modes are most useful for operations which VTOS cannot complete immediately, such as **Read_dev**, **Write_dev**, **Seek_dev**, and certain **Devctl_dev** and **Special_dev** operations on the **COM1:**, **COM2:**, **CPU:**, **PC:**, **REM1:**, and **REM2:** devices.

Pending Device I/O operations may be cancelled by calling **Abort_dev**.

The function prototypes for these services in VTOS.H contain ellipses for the optional NOWAIT mode parameters. When using EVENT_NOTIFY mode with any of these functions in the small and medium memory models, the **`result_ptr`** parameter type must be coerced to **`device_result far*`**. There are two ways it can be done. An identifier which was declared as type **`device_result far*`** may be used. Alternatively, the address of a structure may be passed by using an explicit type cast to **`device_result far*`**. For example:

```
#include <vtos.h>

device_result far* p = Get_buff( size of (device_result) );
device_result result;
word task_id = Get_task_id();

Open_dev( "COM1:", WRITE_MODE, EVENT_NOTIFY, task_id, EF_01, p);
Open_dev( "COM2:", WRITE_MODE, EVENT_NOTIFY, task_id, EF_02,
            (device_result far* )&result );
```

See "Small and Medium Model Differences Between VTOS and MS-DOS" in chapter 8, *Memory Models*, for more information.

Caution

Failure to coerce the `result_ptr` parameter to `far` in small or medium model will result in unexpected operation, possibly including PCM lockup.

Device Driver Support Functions

Table 5-11. Device Driver Support Functions

Function Name	Purpose
Get_next_block	Returns device argument blocks to a VTOS device driver.
Install_dev	Installs a VTOS device driver.
Install_isr	Installs a VTOS interrupt service routine.
Notify_task	Notifies a VTOS task when a device operation completes.

These functions can all be used for installing and operating custom device drivers. A future edition of this manual will discuss VTOS device drivers.

`Install_isr` may also be used to install software interrupt vectors so that two or more tasks can share a single copy of library function code.

Miscellaneous Functions

Table 5-12. Miscellaneous Functions

Function Name	Purpose
Define_led	Defines the function of one of the programmable light-emitting diodes (LEDs).
Get_board_id	Returns the PCM hardware type.
Get_pcm_rev	Returns the revision number of VTOS.
Set_dbd_ctl	Sets the Series 90-70 PCM daughterboard control register.
Set_led	Sets the state of one of the LEDs.
Set_vme_ctl	Sets the VMEbus access parameters in a Series 90-70 PCM.
Where_am_i	Returns the PLC rack / slot location of the PCM.

`Define_led` and **`Set_led`** are used to control the two programmable light-emitting diodes (LEDs). **`Get_board_id`** may be used to determine the PCM hardware type and memory size, **`Where_am_i`** is used to determine its Series 90 PLC rack / slot address, and **`Get_pcm_rev`** returns the PCM firmware version.

`Set_vme_ctl` is used to access memory on the Series 90-70 VMEbus in bus master mode, and **`Set_dbd_ctl`** is used to control custom Series 90-70 PCM daughter boards, such as video controllers.

VTOS Macros

Two VTOS macros are provide to start and end a critical section in which PCM reset or power fail processing will not occur. Critical sections are typically used for linked list maintenance within PCM RAM modules or disk files. Because power fail processing needs to be completed quickly, these macros save a little time by generating inline assembly language instructions rather than using function calls.

Note

The total processing time between BEGIN_CRIT_SECT and END_CRIT_SECT must be limited to 1 millisecond or less.

Caution

Do <u>not</u> make any VTOS function calls inside a critical section.
All accesses to data should be made through `far` pointers.

Table 5-13. VTOS Macros

Type Name	Purpose
BEGIN_CRIT_SECT	Begins a critical section which will not be interrupted by power fail or reset button events.
END_CRIT_SECT	Ends a critical section, allowing power fail and reset processing to occur.

VTOS Types

These data types are defined in VTOS.H:

Table 5-14. VTOS Types in VTOS.H

Type Name	Purpose
arg_blk	Passes information between the PCM device manager and device drivers.
ast_blk	Accesses arguments passed to an asynchronous trap (AST) handler function.
code_hdr	Specifies additional information for executable memory modules.
dcb_blk	Controls data flow between the VTOS device manager and device drivers. Each device has a unique device control block.
device_result	Accesses the completion status and return value of device I/O operations.
env_blk	Specifies the execution environment for executable memory modules.
long_ptr	Accesses the segment and offset parts of a **far** pointer, as an alternative to the Microsoft C FP_SEG and FP_OFF macros.
mod_hdr	Describes each PCM memory module.
special_dev_8_type	Defines the type and offset for PLC data references in the form used by **Special_dev** when called with **special_code**=8.

These data types are defined in CPU_DATA.H:

Table 5-15. VTOS Types in CPU_DATA.H

Type Name	Purpose
cmrq_union	A structure type component of **comreq_msg**. It defines the COMMREQ union type and consists of both the **short_cmrq** and **long_cmrq** structure types.
comreq_msg	Defines COMMREQ messages; it consists of **msg_hdr** and **cmrq_union** members.
cpu_long_status	Defines the CPU long status structure returned by reading the CPU:#LSTAT (CPU Long Status) device.
cpu_rt_clk	A structure type component of **cp_sweep_info**. It defines the CPU scheduler clock structure type.
cpu_short_status	Defines the CPU short status structure type returned by reading the CPU:#SSTAT (CPU Short Status) device. It is approximately equivalent to the PLC_STATUS_INFO_STRUC type defined in STATUS.H.
cpu_stat_flags	A structure type component of **cpu_short_status**. It defines the PLC CPU status flags bit field structure, and is approximately equivalent to the PLC_STATUS_WORD_STRUC type defined in STATUS.H.
cp_sweep_info	A structure type component of **cpu_long_status**. It defines the PLC sweep execution data structure.
cpu_tod	Defines the time and date structure type used to read or write the CPU:#TOD (CPU Time-of-Day clock) device. It contains the current day of the week, and is equivalent to the TIMESTAMP_LONG_STRUC type defined in APITYPES.H.
cpu_tod_sclk	A structure type component of **cpu_sweep_info**. It defines the short (no day of the week) time-of-day clock structure type used to timestamp PLC program changes in **cpu_long_status** and is equivalent to the TIMESTAMP_STRUC type, defined in APITYPES.H.
long_cmrq	A structure type component of **cmrq_union**. It defines COMMREQ messages with msg_type values 0x82 and 0x83 (hexadecimal). These COMMREQs have a separate data buffer.
msg_addr	Defines the bit field structure type which specifies the source and destination of all PLC backplane messages as PLC rack / slot / task addresses. It is used as a member of the **msg_hdr** type.
msg_hdr	Defines the common header structure used by all PLC backplane messages, including COMMREQs.
short_cmrq	A structure type component of **cmrq_union**. It defines COMMREQ messages with msg_type values 0xD2 and 0xD3 (hexadecimal). These COMMREQs contain all their data within the message.
smemreq_msg	Defines the structure type used for read / write system memory service request messages.
svcreq_msg	Defines a generic service request message structure type.

VTOS Global Data

These global variables are defined as **extern** data in VTOS.H:

Table 5-16. VTOS Global Data

Variable Name	Purpose
_VTOS_error	VTOS services which return a completion status also copy their completion (error) code here.

The PLC API Interface

All Series 90 PLC CPUs provide a broad range of services to other Series 90 modules and software processes (for example: Logicmaster 90 software) through a message-based service request interface. The PCM C toolkit provides an application program interface (the PLC API) which hides all the details inside a function call access model. Previously, applications were required to send PLC service request messages (referred to as "generic messages" in the PCM User's Manual, GFK-0255D and later) to use these same services.

Two function calls are provided for each PLC service: a WAIT mode and a NOWAIT mode function. The WAIT mode functions suspend the calling task while the service request is in progress and then return when the request has been completed. NOWAIT requests return immediately, and a status flag is set when each request completes. NOWAIT requests permit a significant reduction of the total time required for multiple requests to be serviced in Series 90-70 PCMs. Note that the application must periodically test a status flag to determine when each PLC API service completes. Event flag and AST notification are not supported for PLC API services.

PLC API Services By Category

This section summarizes PLC API services by grouping them in categories of related services. For full details on all PLC API services, refer to the *PCM C Function Library Reference Manual*, GFK-0772.

Before any of the PLC API services can be used, an API session must be opened with the PLC. The interface must be initialized by calling **api_initialize**, a communication link must be specified by calling **configure_comm_link**, and a channel to the PLC CPU must be opened by calling **establish_comm_session**. See **api_initialize** in the *PCM C Function Library Reference Manual*, GFK-0772, for details.

When the session has been completed, **terminate_comm_session** is called to close the session and free its data.

Table 5-17. Open and Close a PLC API Session

Function Name	Purpose
api_initialize	Initializes PLC API data for a new session.
configure_comm_link	Specifies the communication link to the PLC.
establish_comm_session	Specifies a channel for the CPU: device and returns a session ID.
terminate_comm_session	Ends a PLC API session.

PLC Hardware Type, Configuration, and Status Information

The WAIT mode functions are declared in UTILS.H, and the NOWAIT versions are declared in UTILSNW.H.

Table 5-18. PLC Hardware Type, Configuration, and Status Information

Function Name	Purpose
get_cpu_type_rev get_cpu_type_rev_nowait	Returns the PLC CPU hardware type and firmware revision.
get_memtype_sizes get_memtype_sizes_nowait	Returns the sizes of user-configurable PLC memory types.
chg_priv_level chg_priv_level_nowait	Changes the PLC access privilege level of the calling task.
update_plc_status update_plc_status_nowait	Updates PLC status data in the global structure `plc_status_info`.

PLC Program and Configuration Checksum Data

The WAIT mode functions are declared in CHKSUM.H, and the NOWAIT versions are declared in CHKSUMNW.H.

Table 5-19. PLC Program and Configuration Checksum Data

Function Name	Purpose
get_prgm_info get_prgm_info_nowait	Returns the PLC program checksums.
get_config_info get_config_info_nowait	Returns the PLC configuration data checksums.

Reading PLC Data References

The WAIT mode functions are declared in SYSMEM.H, and the NOWAIT versions are declared in SYSMEMNW.H.

Table 5-20. Reading PLC Data References

Function Name	Purpose
read_sysmem read_sysmem_nowait	Reads up to 2048 bytes of a single PLC reference type.

These WAIT mode functions are declared in PRGMEM.H, and the NOWAIT versions are declared in PRGMEMNW.H.

Table 5-21. Reading Series 90-70 PLC Data References

Function Name	Purpose
read_prgmdata read_prgmdata_nowait	Reads up to 2048 bytes of Series 90-70 %P data.
read_localdata read_localdata_nowait	Reads up to 2048 bytes of Series 90-70 %L data.

Writing PLC Data References

The WAIT mode functions are declared in SYSMEM.H, and the NOWAIT versions are declared in SYSMEMNW.H.

Table 5-22. Writing PLC Data References

Function Name	Purpose
write_sysmem write_sysmem_nowait	Writes up to 2048 bytes of a single PLC reference type.

These WAIT mode functions are declared in PRGMEM.H, and the NOWAIT versions are declared in PRGMEMNW.H.

Table 5-23. Writing Series 90-70 PLC Data References

Function Name	Purpose
write_prgmdata write_prgmdata_nowait	Writes up to 2048 bytes of Series 90-70 %P data.
write_localdata write_localdata_nowait	Writes up to 2048 bytes of Series 90-70 %L data.

Controlling PLC Operation

The WAIT mode functions are declared in CNTRL.H, and the NOWAIT versions are declared in CNTRLNW.H.

Table 5-24. Controlling PLC Operation

Function Name	Purpose
start_plc start_plc_nowait	Sets the PLC state to RUN mode. Series 90-30 outputs are always enabled, but the Series 90-70 output scan state depends on the position of the CPU RUN / STOP switch.
start_plc_noio start_plc_noio_nowait	Sets the PLC state to RUN mode with outputs disabled. (Series 90-70 PLC CPU request only)
stop_plc stop_plc_nowait	Sets the PLC state to STOP mode.

Reading Mixed PLC Data References

The WAIT mode functions are declared in MXREAD.H, and the NOWAIT versions are declared in MXREADNW.H.

Table 5-25. Reading Mixed PLC Data References

Function Name	Purpose
establish_mixed_memory establish_mixed_memory_nowait	Establishes a mixed memory shopping list for subsequent **read_mixed_memory** or **read_mixed_memory_nowait** calls.
read_mixed_memory read_mixed_memory_nowait	Gets the mixed memory data previously specified by an **establish_mixed_memory** or **establish_mixed_memory_nowait** call.
cancel_mixed_memory cancel_mixed_memory_nowait	Cancels the mixed memory shopping list previously specified by an **establish_mixed_memory** or **establish_mixed_memory_nowait** call.

Reading and Clearing PLC and I/O Faults

The WAIT mode functions are declared in CLRFLT.H, and the NOWAIT versions are declared in CLRFLTNW.H.

Table 5-26. Reading and Clearing PLC and I/O Faults

Function Name	Purpose
read_plc_fault_tbl read_plc_fault_tbl_nowait	Reads the entire PLC fault table.
read_io_fault_tbl read_io_fault_tbl_nowait	Reads the entire I/O fault table.
clr_plc_fault_tbl clr_plc_fault_tbl_nowait	Clears the entire PLC fault table.
clr_io_fault_tbl clr_io_fault_tbl_nowait	Clears the entire I/O fault table.

These WAIT mode functions are declared in FAULTS.H, and the NOWAIT versions are declared in FAULTSNW.H.

Table 5-27. Reading Series 90-70 Genius and System Faults

Function Name	Purpose
chk_genius_bus chk_genius_bus_nowait	Determines whether the specified Genius bus on the module in the specified rack and slot has a faulted device. (Series 90-70 PLC CPU request only)
chk_genius_device chk_genius_device_nowait	Determines whether the specified Genius device at the specified bus, rack,,and slot address is faulted. (Series 90-70 PLC CPU request only)
get_one_rackfaults get_one_rackfaults_nowait	Returns all the system fault bits for the specified PLC rack. (Series 90-70 PLC CPU request only)
get_rack_slot_faults get_rack_slot_faults_nowait	Determines which slot or slots, if any, in a specified rack have faulted modules. (Series 90-70 PLC CPU request only)

Reading and Setting the PLC Time-of-Day Clock

The WAIT mode functions are declared in TIME.H, and the NOWAIT versions are declared in TIMENW.H.

Table 5-28. Reading and Setting the PLC Time-of-Day Clock

Function Name	Purpose
read_date read_date_nowait	Returns the current date from the PLC time-of-dayclock.
read_time read_time_nowait	Returns the current time from the PLC time-of-dayclock.
read_timedate read_timedate_nowait	Returns the current time and date from the PLC time-of-day clock in a single operation.
set_date set_date_nowait	Sets the date in the PLC time-of-dayclock.
set_time set_time_nowait	Sets the time in the PLC time-of-dayclock.
set_timedate set_timedate_nowait	Sets the time and date in both the PLC and PCM time-of-day clocks in a single operation.

PLC API Types

These data types are defined in APITYPES.H:

Table 5-29. PLC API Types

Type Name	Purpose
BOOLEAN	Unsigned char type which takes the values TRUE and FALSE only.
BYTE	Unsigned char type which takes the values 0 through 255 decimal.
CONFIG_INFO_STRUC	A structure type returned by **`get_config_info`** and **`get_config_info_nowait`**
CPU_TYPE_STRUC	A structure type returned by **`get_cpu_type_rev`** and **`get_cpu_type_rev_nowait`**
DATE_LONG_STRUC	A structure type returned by **`read_date`** and **`read_date_nowait`**, and passed to **`set_date`** and **`set_date_nowait`**
DATE_STRUC	A structure type component of IO_FAULT_TBL_STRUC and PLC_FAULT_TBL_STRUC.
FAULT_HDR_STRUC	A structure type component of IO_FAULT_TBLSTRUC and PLC_FAULT_TBL_STRUC.
IO FAULT STRUC	A structure type component of IO_FAULT_TBL_STRUC.

Type Name	Purpose
IO_FAULT_TBL_STRUC	A structure type returned by **read_io_fault_tbl** and **read_io_fault_tbl_nowait**
MEM_SIZES_STRUC	A structure type returned by **get_memtype_sizes** and **get_memtype_sizes_nowait**
PLC_FAULT_STRUC	A structure type component of PLC_FAULT_TBL_STRUC.
PLC_FAULT_TBL_STRUC	A structure type returned by **read_plc_fault_tbl** and **read_plc_fault_tbl_nowait**
PROGRAM_INFO_STRUC	A structure type returned by **get_prgm_info** and **get_prgm_info_nowait**
RACK_FAULT_STRUC	A structure type returned by **get_one_rackfaults** and **get_one_rackfaults_nowait**
RACK_SLOT_STRUC	A structure type component of RACK_FAULT_STRUC.
TIMESTAMP_LONG_STRUC	A structure type returned by **read_timedate** and **read_timedate_nowait**, and passed to **set_timedate** and **set_timedate_nowait.**
TIMESTAMP_STRUC	A structure type component of IO_FAULT_TBL_STRUC and PLC_FAULT_TBL_STRUC.
TIME_STRUC	A structure type returned by **read_time** and **read_time_nowait**, and passed to **set_time** and **set_time_nowait**
WORD	Unsigned short int type which takes the values 0 through 65,535 decimal.

These data types are defined in MIXTYPES.H.

Table 5-30. Data Types

Type Name	Purpose
MEM_FORMAT_STRUC	A structure type component of MIXED_MEMORY_READ_STRUC.
MIXED_MEMORY_READ_STRUC	Structure type passed to **establish_mixed_memory** and **establish_mixed_memory_nowait**.

PLC API Global Data

These global variables are defined as extern data in STATUS.H:

Table 5-31. PLC API Global Data

Variable Name	Purpose
plc_status_info	This is an array of type PLC_STATUS_INFO_STRUC, containing MAX_SESSIONS elements. When each PLC API service request completes, it updates the **plc_status_info** element corresponding to the **session_id** value passed to it when it was called. Note that **update_plc_status** and **update_plc_status_nowait** have no other effect than updating an element of this array.

Using Standard C Libraries

Most standard C library functions may be used with PCM C applications. However, there are some restrictions, described below. Other Microsoft C runtime library functions, such as MS-DOS services and graphics, are not supported by PCM hardware and / or VTOS. Appendix A, *Microsoft Runtime Library Support*, provides a complete reference on the suitability of each Microsoft C 6.0 runtime library function for PCM applications.

Restrictions

Many standard C library functions are supported without restriction in all the Intel memory models supported by the PCM. However, the actual Microsoft library code is not always used. In some cases, a C preprocessor macro defined in a PCM header file substitutes a different Microsoft library function call. In other cases, code provided with the PCM C toolkit replaces code in the Microsoft library. These substitutions occur as a result of the order in which libraries are specified to the Microsoft linker.

Other functions may be used without restrictions in large model applications, but restrictions apply in small and medium models. VTOS uses separate data and stack segments even in the small and medium models. Consequently, many functions which take pointers as parameters are restricted in small and medium models to DS-based addresses (addresses of global or static variables) for these parameters. A few functions may be used only in large model.

Caution

There is no enforcement of these restrictions. The user is responsible for avoiding the use of unsupported functions and for the correct use of conditionally supported functions.

Errors will occur when unsupported functions are used or conditionally supported functions are used incorrectly. The consequences range from immediate PCM lockup to intermittent or minor errors with no apparent connection to the unsupported or conditionally supported function.

Every C source file which calls one or more standard C library functions **must** include all the header files where the prototypes for those functions are defined. This is **absolutely essential** in the small and medium memory models.

Caution

Failure to include header files where prototypes for standard C library functions are defined will often result in PCM lockup or unexpected operation.

Using printf In Small and Medium Models

The function prototypes for **printf** and its relatives (**fprintf**, **sprintf**, and **vprintf**; see STDIO.H) specify that the control string parameter is a **far** pointer. However, the balance of the parameter list is unspecified, as indicated by the ellipsis. The VTOS library code for these functions assumes that all data pointers are **far** in all memory models. When using any of these functions in the small or medium model to print strings (the %s format specifier), the character pointer parameters must be coerced to type **char far***. There are two ways it can be done. A pointer identifier which was declared as type **char far*** may be used. Alternatively, a string literal may be type cast explicitly to **char far***. For example:

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

char far* s = "Hello";
printf( "%s %s\n", s, (char far* )"world!" );
```

See "Small and Medium Model Differences Between VTOS and MS-DOS" in chapter 8, *Memory Models*.

Caution

Failure to coerce printf data pointers to far in small or medium model will result in unexpected operation, possibly including PCM lockup.

Header Files

The PCM C toolkit provides these header files:

Table 5-32. VTOS Header Files

PCM Header File	Description
CTOS.H PCMCSARG.H PCMLIB.H	These PCM header files are not used by release 1.00 or later of the PCM C toolkit. They are furnished to provide backward compatibility with previous, unreleased versions of the toolkit. In this release, these files simply **#include** the files **STDARG.H** and **VTOS.H**, respectively.
VTOS.H	Provides type definitions and function prototypes for all VTOS operating system services.
CPU_DATA.H	Defines PLC CPU data types which are used by VTOS services.

Table 5-33. PLC API Header Files

PLC API Header File	Description
APITYPES.H CHKSUM.H CHKSUMNW.H CLRFLT.H CLRFLTNW.H CNTRL.H CNTRLNW.H FAULTS.H FAULTSNW.H MEMTYPES.H MIXTYPES.H MXREAD.H MXREADNW.H PRGMEM.H PRGMEMNW.H SESSION.H STATUS.H SYSMEM.H SYSMEMNW.H TIME.H TIMENW.H UTILS.H UTILSNW.H	These files provide type definitions and function prototypes for PLC API services, as described earlier in this chapter. Each file provides a small group of related services.

Table 5-34. Microsoft Replacement Header Files

Microsoft Replacement Header Files	Description
EXT.H MALLOC.H MEMORY.H STDARG.H STDIO.H STDLIB.H STRING.H	These header files must be included **instead** of the Microsoft header files of the same name. In addition, the appropriate PCM library (**`PCMS.LIB`**, **`PCMM.LIB`**, or **`PCML.LIB`**) must appear **before** any Microsoft libraries in the Microsoft linker command line or the **`LIB`** environment variable.

Chapter 6 PCM Real-Time Programming

PCM applications typically process unpredictable events such as operator intervention and incoming messages from the serial ports or PLC backplane. The techniques for detecting events like these and responding within a predictable time are often referred to as *real-time programming*. This chapter discusses real-time programming under the PCM's VTOS operating system.

Asynchronous Events

Application tasks are typically structured as non-terminating loops. Events which occur at random times in relation to execution of the loop are often referred to as *asynchronous events*. VTOS provides mechanisms for handing three kinds of asynchronous events:

1. Incoming communication from the PCM serial ports or PLC backplane;
2. Completion of slow file I/O operations on the PC:, REM1: or REM2: devices; and
3. Timer timeout events.

There are two separate mechanisms for handling asynchronous events: asynchronous traps (ASTs) and event flags. Both are built on the 80186/80188 microprocessor hardware interrupt mechanism. They provide alternate, abstract views of asynchronous events at a higher (and safer) level of abstraction than hardware interrupts. Either of these mechanisms may be specified for each VTOS I/O and timer service request.

VTOS Asynchronous I/O Scenario

When a PCM application task makes a VTOS device I/O service call, one of the function parameters specifies the method which VTOS will use to notify the task when the request completes. If the task specified WAIT mode, the service call does not return until the requested operation has completed. The calling task is blocked while the operation is in progress. This mode is referred to as *synchronous I/O* because task execution is synchronized with completion of the I/O request. WAIT mode provides programming simplicity at a cost:

1. A task may have only one I/O operation in progress at a time.
2. If a malfunction occurs, and the I/O operation never completes, the calling task will resume execution only if and when the operation is aborted by a different task or an asynchronous timeout.

Alternatively, the application task may specify EVENT_NOTIFY or AST_NOTIFY mode. For either of these modes, the service call returns immediately. The calling task may make additional I/O requests or perform other operations while the I/O request is in progress. When the request completes, this chain of events is set in motion:

1. A hardware interrupt is asserted by the PCM serial controller or backplane I/O hardware;
2. The microprocessor hardware interrupt mechanism transfers control to a VTOS interrupt service routine (ISR). The details of I/O processing depend on which physical device is involved and how it was opened by the application.
3. When processing is complete, VTOS notifies the application either by setting a local event flag or posting an AST, as specified in the request.

What happens next depends on whether event flag or AST notification was used. The narrative continues in one of the following sections: "Local Event Flag Notification" or "AST Notification and Execution Threads," as appropriate.

VTOS Asynchronous Timer Scenario

The VTOS **`Start_timer`** service also permits the calling task to specify local event flag or AST notification. Up to 32 timers may be in use simultaneously by all tasks. The most common uses of VTOS timers are:

1. Triggering processes which the task must perform on a periodic basis; and
2. Timing out I/O operations which do not complete so that they can be aborted cleanly.

This sequence of events occurs when a timer expires:

1. A PCM hardware timer asserts a timer interrupt whenever a timer is scheduled to expire.
2. The timer interrupt service routine resumes execution of the VTOS real-time clock (RTC) task, pre-empting whatever task was executing.
3. The RTC task determines which timer or timers have expired. It sets a local event flag or posts an AST, as specified when the timer was started, to the task which owns each of the expired timers.

Depending on whether event flag or AST notification was used, the section "Local Event Flag Notification" or "AST Notification and Execution Threads," respectively, describes what happens next.

Local Event Flag Notification

If an application task uses the EVENT_NOTIFY option for a device operation or timer, VTOS sets a specified local event flag when the I/O completion or timeout event occurs. The task can have two or more device operations and/or timers in progress at the same time. However, different event flags must be specified for each one, to permit the task to identify events as they occur.

Once the application has started all the I/O operations and timers it needs, it can wait for one of the pending I/O completion or timeout events to occur by calling **`Wait_ef`**. A set of event flags is specified as a parameter in the call, and the function will not return until one of the specified event flags is set. If one has been set before the call, **`Wait_ef`** returns immediately. Otherwise, execution of the calling task is suspended.

When any local event flag is set, VTOS determines whether the task which owns it is waiting for that flag. If so, the task is made ready, and the VTOS scheduler compares its priority to the task which was executing when the event or events occurred. The waiting task resumes execution and returns from the **`Wait_ef`** call when it has the highest priority of all the tasks which are ready to execute.

When **`Wait_ef`** returns, the task can determine which event or events have occurred by calling **`Test_ef`** and checking to see which event flags have been set.

Whenever notification is not required for a device operation, you can use EVENT_NOTIFY and specify no event flags at all. Simply use zero (0) as the **`local_ef_mask`** parameter for the function call.

AST Notification and Execution Threads

An application task may also specify AST_NOTIFY as the method of notification for an event. One of the parameters in an AST_NOTIFY service request call is the address of a function which is referred to as the AST function for the event. When the event occurs, VTOS posts an AST to the task.

VTOS tasks may be thought of as having two independent execution threads: the mainline or normal thread and the AST thread. The mainline thread is simply the task's **`main`** function plus the functions called directly or indirectly from it. The AST thread consists of the task's AST functions plus any functions which they call directly or indirectly.

If the task's mainline thread is executing when an AST is posted to the task, that thread is interrupted. VTOS calls the AST function associated with the AST. When the AST function returns, the mainline thread resumes execution at the point where it was interrupted.

If the task is not executing when the AST is posted (because it was pre-empted by a higher priority task, for example), execution of the AST function is delayed until the task becomes the highest priority task which is ready to run. If more than one AST has been posted while the task was pre-empted, the corresponding AST functions are executed in the order in which they were posted. When the last AST function returns, the task's mainline code resumes execution at the point where it was pre-empted.

Note

If the task is waiting for completion of WAIT mode I/O or for local or global event flags when the AST is posted, execution does not resume until the I/O operation completes or the event flags are set.

When VTOS calls an AST function, a pointer to an **ast_blk** structure is passed as the only parameter. For an I/O operation, the **ast_blk** contains the completion status of the operation. When a timer AST function is called, the structure contains a value which identifies the timer which expired.

The application may suspend itself to wait for one or more AST_NOTIFY events to occur by calling **Wait_ast**. When one of the events occurs, the corresponding AST function executes as soon as the task has the highest priority of all the tasks which are ready. When the AST function returns, the task's call to **Wait_ast** will return.

Strategies For Predictable Real-Time Performance

There is no single "best way" to design real-time PCM applications. Every application has a unique set of requirements. WAIT mode event processing fits some requirements very well and has the advantage of simplicity. Of the asynchronous techniques, EVENT_NOTIFY processing requires the smallest VTOS processing overhead. It is well suited to applications where events must be processed in a fixed order. AST_NOTIFY processing requires the most VTOS overhead, but is well suited to applications where events must be processed in order of their occurrence.

Using WAIT Mode Event Processing

For example, suppose that the requirements of a PLC application specify that a certain safety-related condition must be monitored continuously, and that an alarm message must be sent to a supervisory computer within a given time after the condition occurs. Assume further that a transition contact in the PLC CPU has been assigned to represent the specified condition. When the contact closes, the PLC ladder program sends a COMMREQ message to the PCM. A PCM application task is required to detect the COMMREQ and send the alarm message from PCM serial port 2.

Here is a short example program showing how this requirement could be met using WAIT mode event processing.

```
/* ALARM.C */
#include <vtos.h>
#include <cpu_data.h>

void send_serial_alarm(word handle);
void respond_to_comreq(word handle);

byte comreq_buf [COMREQ_MSG_SIZE];

void main(void)
{
    word serial_hndl, comreq_hndl, task_id;

    task_id = Get_task_id();
    serial_hndl = Open_dev("COM2:", WRITE_MODE, WAIT, task_id);
    comreq_hndl = Open_dev("CPU:#6", WRITE_MODE, WAIT, task_id);

    for (;;) {
       if (Read_dev(comreq_hndl, comreq_buf, COMREQ_MSG_SIZE, WAIT, task_id)
             == COMREQ_MSG_SIZE) {
          send_serial_alarm(serial_hndl);
          respond_to_comreq(comreq_hndl);
       }
    }
}
```

The program in this example, ALARM.C, opens two I/O channels and then enters a non-terminating loop. One of the channels receives the COMMREQ from the PLC CPU; the other sends the alarm message to the supervisor. Note that the COMMREQ channel is opened on device **"CPU:#6"**. The PLC COMMREQ function block which sends the COMMREQ message must use 6 as the value of its TASK_ID parameter.

In the loop, a **Read_dev** request is made in WAIT mode. Normally, this function call does not return until a message is received which contains COMREQ_SIZE bytes. However, the **Read_dev** request could be aborted by another task. If so, fewer than COMREQ_MSG_SIZE characters would be returned. Consequently, the program checks the number of bytes read by **Read_dev**. If the data size is correct, the function **send_serial_alarm** is called to send the alarm, and **respond_to_comreq** is called to write a non-zero value to the COMMREQ status pointer location in the PLC CPU. The implementation of these functions is beyond the scope of this example. For more information on COMMREQs, refer to "Communications Request (COMMREQ) Messages from PLC Programs" in chapter 4, *Using PCM Resources*.

ALARM.EXE should be run as a priority-based VTOS task with priority (that is, ID value) 5, the highest priority which should be used by any application task. This command line in a PCMEXEC.BAT file could be used:

```
R ALARM.EXE /I5
```

Once ALARM.EXE enters the loop, it executes only when the condition it monitors has actually occurred. If this is a rare event, ALARM.EXE will require very little PCM processor time, on average. One or more additional application tasks can run in this same PCM, as long as they execute at lower priority (higher ID values).

Using EVENT_NOTIFY Mode Event Processing

For the purpose of illustrating EVENT_NOTIFY processing, assume that a simple operator interface is required. This interface has two functions: sending the first 100 PLC register (%R) values to the operator interface terminal (OIT) once per second, and receiving operator commands from the terminal. Operator commands must be acted upon immediately when they arrive. The program OIT_DRVR.C shows how these requirements might be met.

```
/* OIT_DRVR.C */
#include <vtos.h>

#define CMD_RECEIVED       EF_00
#define REGS_RECEIVED      EF_01
#define READ_REGS          EF_02
#define DEAD_PLC           EF_03
#define TASK_FLAGS(CMD_RECEIVED | REGS_RECEIVED | READ_REGS |
                                     DEAD_PLC)

#define COMMAND_SIZE          84
#define REG_SIZE             100
#define REG_READ_TIME       1000    /* one second */
#define DEAD_PLC_TIME       5000    /* five seconds */

byte Command [COMMAND_SIZE];
word Regs [REG_SIZE];

/*
 * These function prototypes specify functions which are beyond the scope
 * of this example.
 */

void process_command(byte far* cmd_ptr);
void display_registers(word handle, word far* data_ptr);
void display_bad_regs_alarm(word handle);
void display_dead_plc_alarm(word handle);

void main(void)
{
    device_result command_result, regs_result;
    word        oit_hndl, regs_hndl, task_id;
    word        read_timer, dead_plc_timer, local_flags;
    word        read_pending = 0;
```

```
    Reset_ef(TASK_FLAGS);
    Set_ef(READ_REGS);
    task_id = Get_task_id();
    oit_hndl = Open_dev("COM1:13", WRITE_MODE, WAIT, task_id);

    regs_hndl = Open_dev("CPU:%R1",
             READ_MODE | NATIVE_MODE | AUTO_REWIND_MODE,
             WAIT, task_id);
    Read_dev(oit_hndl, Command, COMMAND_SIZE, EVENT_NOTIFY,
             task_id, CMD_RECEIVED,
             (device_result far* )&command_result);
    read_timer = Start_timer(RELATIVE_TIMEOUT | REPEAT_MODE,
             MS_COUNT_MODE, 0, REG_READ_TIME, READ_REGS);

    for (;;) {
       local_flags = Test_ef();
       Reset_ef(local_flags);

       if (local_flags & CMD_RECEIVED ) {
          if (command_result.ioresult == SUCCESS) {
             process_command(Command);
          }
          Read_dev(oit_hndl, Command, COMMAND_SIZE, EVENT_NOTIFY,
                      task_id, CMD_RECEIVED,
                      (device_result far* )&command_result);
       }

       if (local_flags & REGS_RECEIVED) {
          Cancel_timer(dead_plc_timer);
          read_pending = 0;
          if (regs_result.ioreturn != REG_SIZE) {
             display_bad_regs_alarm(oit_hndl);
          } else {
             display_registers(oit_hndl, Regs);
          }
       }

       if ((local_flags & READ_REGS) && !read_pending) {
          Read_dev(regs_hndl, Regs, REG_SIZE, EVENT_NOTIFY, task_id,
                      REGS_RECEIVED,(device_result far* )&regs_result);
          read_pending = 1;
          dead_plc_timer = Start_timer(RELATIVE_TIMEOUT, MS_COUNT_MODE, 0,
                      DEAD_PLC_TIME, DEAD_PLC);
       }

       if (local_flags & DEAD_PLC) {
          Abort_dev(regs_hndl, ABORT_ALL, 0);
          read_pending = 0;
          display_dead_plc_alarm(oit_hndl);
       }
       Wait_ef(TASK_FLAGS);
    }
}
```

OIT_DRVR.C recognizes four events:

1. A command has been received from the OIT.
2. Register data has been received from the PLC CPU.
3. It is now time to request PLC register data.
4. The last request to read PLC registers has timed out and no data has arrived.

Each of these events is assigned a unique local event flag in **`#define`** macros. The non-terminating **`for (;;)`** loop waits for one or more of them to occur. If two or more of the events occur, they are processed in a fixed order, determined by the order of **`if`** conditions in the loop.

Before entering the loop, the task opens separate I/O channels for reading commands from the OIT, displaying values and alarm messages to the OIT, and reading PLC register values.

The first read request for an OIT command is also made before entering the loop. However, the first read request for PLC register data is made in the loop, triggered by setting the READ_REGS event flag before the loop is entered. The timer which triggers register requests on a constant time interval is started in REPEAT_MODE so that processing time will not increase the interval between requests. The automatic variable **`read_pending`** prevents making a register read request before the previous one has completed. Another timer is started to time out the read request in case there is a malfunction.

In the loop, the task waits for one or more of the local event flags of interest to be set. When the **`Wait_ef`** call returns, the current values of all the task's local flags are obtained by calling **`Test_ef,`** and the flags of interest are cleared by calling **`Reset_ef`**. Then, the word containing the event flags is tested by a separate **`if`** statement for each event. The tests occur in the order of importance for the events. When one of the events has occurred, the appropriate action is taken:

1. If a command was received from the OIT, its length is checked. If the command length is correct, the command is processed. A read operation is requested for the next command.
2. If register data was received, the timeout is cancelled and the data is checked for the correct length. If the length is correct, the data is sent to the OIT for display.
3. If the time has arrived to request new register data and no read request is still pending, a read request is sent and the timeout is started.
4. If the register read timeout has expired, the read request is aborted and the OIT is notified.

The purposes of the functions **`process_command`**, **`display_registers`**, **`display_bad_regs_alarm`**, and **`display_dead_plc_alarm`** should be evident from their names; the details are not considered here.

Using AST_NOTIFY Mode Event Processing

Finally, here is an example where AST_NOTIFY event processing is most appropriate. In this case, we assume that events are required to be processed in the order they occur.

The PCM application periodically receives a COMMREQ message from the PLC CPU which contains PLC register values. When a COMMREQ arrives, the values are sent out serial port 1 to an operator interface terminal (OIT). The program acknowledges the COMMREQ by writing to the PLC data location specified by the COMMREQ status pointer.

The OIT may send a command which contains new register values. When a command arrives, the new values are written to the PLC CPU.

The **`Write_dev`** operations which acknowledge the COMMREQ, send register data to the OIT, and write new register data to the PLC CPU all use AST notification. Each one also uses a timer with AST notification to abort the write operation when it does not complete. In addition, **`Read_dev`** calls using AST notification receive the COMMREQ and OIT command.

There are a total of eight I/O operations and timers. Each I/O completion or timeout is an event for the program to process. Figure 6.1 is a state transition diagram which shows how the example program processes these events.

The arrows in Figure 6.1 represent events, and the circles represent states. The arrows pointing away from the center circle are labeled with the name of an event. When one of the named events occurs, the state of the program transitions from the state at start of the corresponding arrow to the state at the tip of the arrow. The state at the tip is said to be the successor of the state at the root of the arrow.

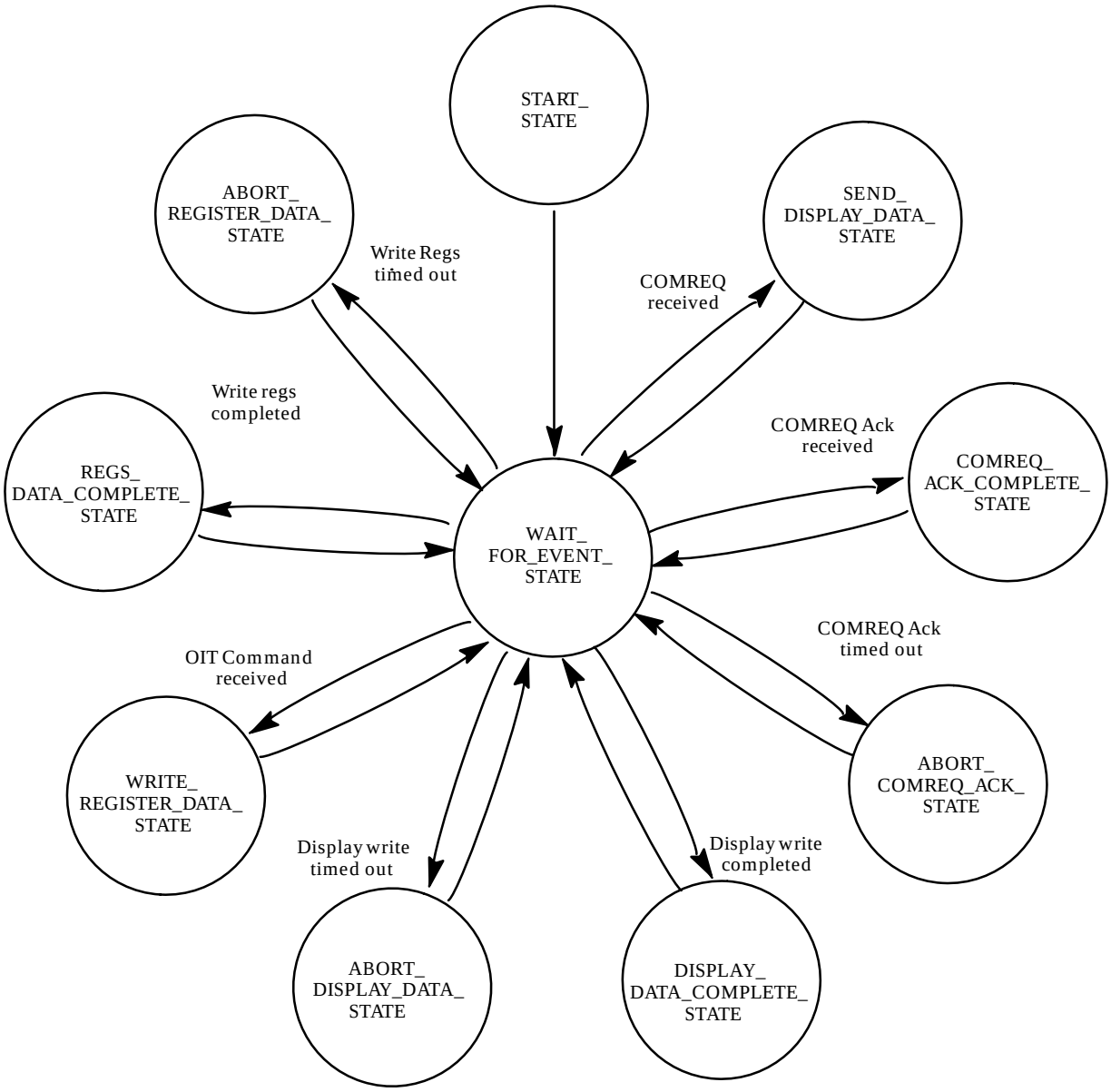


Figure 6.1 State Transition Diagram Of AST Based Example

Each state which is triggered by an event has one or more actions that the program takes when it is in that state. When all the actions of a particular state are completed, another state transition takes place, through the unlabeled arrow leading away from that state.

The program's **main** function begins with START_STATE, where the actions initialize variables and open I/O channels. The **for (;;)** loop in **main** never terminates; it is WAIT_FOR_EVENT_STATE. The actions for all the other states are in the eight AST functions. Each AST function contains code to perform all the actions for the program state in its identifier. A comment in each AST function names the event which triggers it.

```
#include <vtos.h>
#include <memory.h>
#include <cpu_data.h>

#define COMMAND_SIZE               16
#define REG_SIZE                  100
#define OIT_FORMAT_WIDTH            6  /* display width of %R data in chars */
#define ACK_TIMEOUT              5000  /* five seconds */
#define DISPLAY_TIMEOUT          5000  /* five seconds */
#define REGS_TIMEOUT             5000  /* five seconds */
#define CMRQ_MSG_SIZE              32
#define MAX_CMRQ_DATA             256
#define CMD_READ_HNDL              92
#define REGS_ACK_HNDL              93
#define REGS_TIMEOUT_HNDL          94
#define DISPLAY_ACK_HNDL           95
#define DISPLAY_TIMEOUT_HNDL       96
#define CMRQ_TIMEOUT_HNDL          97
#define CMRQ_ACK_HNDL              98
#define CMRQ_READ_HNDL             99
#define STAT_VALUE                  1
#define DONT_CARE                   0

comrmeq_msg Cmrq_msg;                          /* storage for PLC COMREQs */
word New_regs [REG_SIZE];               /* storage for new %R values from OIT */
char Display_data [OIT_FORMAT_WIDTH * REG_SIZE]/* formatted %R data storage */
byte Command [COMMAND_SIZE];                    /* storage for OIT commands */
word Plc_regs [MAX_CMRQ_DATA/sizeof(word)];       /* %R values from COMREQs */
word Task_id;                           /* ID value of this program's VTOS task */
word Cmrq_hndl;                         Open_dev handle for reading PLC COMREQs */
word New_regs_hndl;           Open_dev handle for writing new %R data to PLC */
word Cmrq_ack_hndl;                Open_dev handle for writing COMREQ status */
word Oit_hndl;          /* Open_dev handle for OIT commands and display data */
word Cmrq_ack_timeout;                  /* timer handle for COMREQ ack write */
word Display_ack_timeout;                /* timer handle for OIT data write */
word Regs_ack_timeout;          /* timer handle for new %R data write to PLC */

/* CMRQSTAT.C */
/*
 * These function prototypes specify functions which are beyond the scope
 * of this example.
 */
void recover_from_error(word op_handle, word error_code);
void process_command(byte far* cmd_ptr);
void display_dead_plc_alarm(word handle);
word format_display_data(char far* formatted_data, word far* binary_data,
             word num_registers);

void far COMREQ_ACK_COMPLETE_STATE_ast( ast_blk far* ast_ptr )
{
/* The Write_dev to acknowledge the COMREQ completed. */

    if (ast_ptr->handle == CMRQ_ACK_HNDL && ast_ptr->arg1 == SUCCESS) {
       Cancel_timer(Cmrq_ack_timeout);
    } else {
       recover_from_error(CMRQ_ACK_HNDL, ast_ptr->arg2);
    }
}
```

```
void far ABORT_COMREQ_ACK_STATE_ast( ast_blk far* ast_ptr )
{
/* The Write_dev to acknowledge the COMREQ timed out. */

    Abort_dev(Cmrq_ack_hndl, ABORT_ALL, 0);
    display_dead_plc_alarm(Oit_hndl);
}

void far DISPLAY_ACK_COMPLETE_STATE_ast( ast_blk far* ast_ptr )
{
/* The Write_dev to display PLC register data on the OIT completed. */

       Cancel_timer(Display_ack_timeout);
}

void far ABORT_DISPLAY_DATA_STATE_ast( ast_blk far* ast_ptr )
{
/* The Write_dev to display PLC register data on the OIT timed out. */

    Abort_dev(Oit_hndl, ABORT_ALL, 0);
}

void far SEND_DISPLAY_DATA_STATE_ast( ast_blk far* ast_ptr )
{
/* A COMREQ was received. */

    word display_size, cmrq_data_size, send_count, status = STAT_VALUE;
/*
 * Do an AST_NOTIFY read for the next COMREQ.
 */
    Read_dev(Cmrq_hndl, &Cmrq_msg, CMRQ_MSG_SIZE, AST_NOTIFY, Task_id,
                  SEND_DISPLAY_DATA_STATE_ast, CMRQ_READ_HNDL);

/*
 * Get the COMREQ data.
 */
    if (Cmrq_msg.header.msg_type & 0x40) {      /* there is no data buffer */
       cmrq_data_size = 12;
       memcpy(Plc_regs, Cmrq_msg.data.short_c.data, size);
    } else {
/*
 * there is a data buffer */
       cmrq_data_size = Cmrq_msg.data.long_c.data_size;
       Read_dev(Cmrq_hndl, Plc_regs, cmrq_data_size, WAIT, Task_id);
    }
/*
 * Send a COMREQ acknowledgement to the PLC CPU.
 */
    Write_dev(Cmrq_ack_hndl, &status, 1, AST_NOTIFY, Task_id,
              COMREQ_ACK_COMPLETE_STATE_ast, CMRQ_ACK_HNDL);
    Cmrq_ack_timeout = Start_timer(RELATIVE_TIMEOUT | AST_NOTIFY_MODE,
              MS_COUNT_MODE, 0, ACK_TIMEOUT,
              ABORT_COMREQ_ACK_STATE_ast, CMRQ_TIMEOUT_HNDL);
/*
 * Display the data.
 */
    display_size = format_display_data(Display_data, Plc_regs,
              cmrq_data_size/sizeof(word));
    Write_dev(Oit_hndl, Display_data, display_size, AST_NOTIFY,
          Task_id, DISPLAY_ACK_COMPLETE_STATE_ast, DISPLAY_ACK_HNDL);
    Display_ack_timeout = Start_timer(RELATIVE_TIMEOUT | AST_NOTIFY_MODE,
              MS_COUNT_MODE, 0, DISPLAY_TIMEOUT,
              ABORT_DISPLAY_DATA_STATE_ast, DISPLAY_TIMEOUT_HNDL);
}
```

```
void far REGS_DATA_COMPLETE_STATE_ast(ast_blk far* ast_ptr )
{
/* The Write_dev for new PLC register data completed. */

    Cancel_timer(Regs_ack_timeout);
}

void far ABORT_REGISTER_DATA_STATE_ast(ast_blk far* ast_ptr )
{
/* The Write_dev for new PLC register data timed out. */

    Abort_dev(New_regs_hndl, ABORT_ALL, 0);
    display_dead_plc_alarm(Oit_hndl);
}

void far WRITE_REGISTER_DATA_STATE_ast(ast_blk far* ast_ptr )
{
/*
/* A command was received from the OIT.
 * Do an AST_NOTIFY read for the next command.
 */
    Regs_ack_timeout = Start_timer(RELATIVE_TIMEOUT | AST_NOTIFY_MODE,
                MS_COUNT_MODE, 0, REGS_TIMEOUT,
                ABORT_REGISTER_DATA_STATE_ast, REGS_TIMEOUT_HNDL);
/*
 * Process the command and send the new %R data to the PLC CPU.
 */
    process_command(Command);
    Write_dev(New_regs_hndl, New_regs, REG_SIZE, AST_NOTIFY, Task_id,
                REGS_DATA_COMPLETE_STATE_ast, REGS_ACK_HNDL);
}

void main( void )
{
/*
 * Get the task ID of this task from VTOS.
 */
     Task_id = Get_task_id();
/*
 * Open PLC CPU channels for acknowledging COMREQs and sending new register
 * values.
 */
    Cmrq_ack_hndl = Open_dev("CPU:%R200",
                WRITE_MODE | NATIVE_MODE | AUTO_REWIND_MODE,
                WAIT, Task_id);
    New_regs_hndl = Open_dev("CPU:%R1",
                WRITE_MODE | NATIVE_MODE | AUTO_REWIND_MODE,
                WAIT, Task_id);
/*
 * Open a COMREQ channel for reads.
 */     Cmrq_hndl = Open_dev("CPU:#5", READ_MODE, WAIT, Task_id);
/*
 * Open a read/write channel to the Operator Interface Terminal.
 */
    Oit_hndl = Open_dev("COM1:13", READ_MODE | WRITE_MODE, WAIT, Task_id);
/*
 * Do an AST_NOTIFY read for the first COMREQ and command.
 */
    Read_dev(Cmrq_hndl, &Cmrq_msg, CMRQ_MSG_SIZE, AST_NOTIFY, Task_id,
                SEND_DISPLAY_DATA_STATE_ast, CMRQ_READ_HNDL);
    Read_dev(Oit_hndl, Command, COMMAND_SIZE, AST_NOTIFY, Task_id,
                WRITE_REGISTER_DATA_STATE_ast, CMD_READ_HNDL);
/*
 * Start of WAIT_FOR_EVENT_STATE.
 */
    for (;;) {
       Wait_ast();
    }
}
```

To make this somewhat lengthy example as brief and clear as possible, a few details have been omitted. The function **process_command** is assumed to move the new register data to the **New_regs** array, but the details of **process_command** are not shown. The implementation of **display_dead_plc_alarm** is omitted. PLC register data is assumed to be formatted for OIT display by calling **format_display_data**. Finally, code to check error conditions has been omitted from all the AST functions except **COMREQ_ACK_COMPLETE_STATE_ast**, but the details of **recover_from_error** are also omitted.

Note that the structure of this example is very simple. Each of the event-triggered states has only one successor state, WAIT_FOR_EVENT_STATE. At any given time, the possible successor states of WAIT_FOR_EVENT_STATE are determined by the events which may occur, based on the program's recent history. There is no program logic at all to select successor states.

Differences between ASTs and MS-DOS ISRs

MS-DOS interrupt service routines (ISRs) are different from VTOS asynchronous traps in many ways. Making MS-DOS service requests from ISRs often causes errors when the interrupted code is MS-DOS itself. In addition, the time which can be spent executing ISR code is usually limited.

Neither of these considerations applies to VTOS asynchronous traps. The AST thread of a VTOS task may use almost any VTOS service (although it is **not** safe to call **Disable_asts** from the AST thread in VTOS versions earlier than 3.00). After initialization, a VTOS task may spend virtually all its time executing the AST thread. The example program, above, demonstrates how all the real work of an application can be done in AST functions.

One common programming technique is specifically **not** recommended for VTOS. MS-DOS ISRs are often used to set flags or condition codes which then control execution of the main program. Under VTOS, using ASTs to set condition codes or flags is **very** inefficient. VTOS event flags are the preferred method.

Other Considerations When Using Asynchronous Traps

The far Keyword

In small model, the **far** keyword is required with AST function identifiers. It is good practice to include **far** in all models.

Processing in Both Main and AST Threads

Although it is a bad programming practice to use ASTs just to set flags or condition codes for the main thread, flags are often necessary to divide a task's processing between both threads. This program fragment illustrates a problem which can occur when the AST sets a flag used in the main thread.

```
#include <vtos.h>
#include <dos.h>

word Input_size;

void far serial_input_ast(ast_blk far* ast_ptr)
{
/*
 * Do something useful.
 */
    Input_size = ast_ptr->arg2;
}

void main(void)
{
    char input_data [MAX_INPUT];
    word task = Get_task_id();
    word serial_p1 = Open_dev("COM1:13", READ_MODE, WAIT, task);

    for (;;) {
       Input_size = 0;
       Read_dev(serial_p1, input_data, MAX_INPUT, AST_NOTIFY, task,
                  serial_input_ast);
       if (Input_size == 0) {
          Wait_ast();
       }
/*
 * Do something with the input data.
 */
    }
 }
```

This program waits for input on PCM serial port 1, which was opened with the option to terminate read requests when ASCII code 13 (CR) arrives. If input characters with a terminating CR character are already in the COM1: type-ahead buffer, **serial_input_ast** will be called before **input_size** is tested in the **if** condition. However, it is possible for the CR character to arrive just in time for VTOS to call **serial_input_ast** after the test but before the call to **Wait_ast**. When this happens, the program will hang until some other AST occurs, if ever.

The problem can be avoided by preventing VTOS from posting ASTs between the test and **Wait_ast** call, as shown here. Only the **for (;;)** loop has changed:

```
    for (;;) {
       Input_size = 0;
       Read_dev(serial_p1, input_data, MAX_INPUT, AST_NOTIFY, task,
                   serial_input_ast);
       _disable();
       if (Input_size == 0) {
          Wait_ast();
       }
       _enable();
/*
 * Do something with the input data.
 */
    }
```

Both **_disable** and **_enable** are Microsoft library functions defined in DOS.H. They disable and enable maskable hardware interrupts, respectively, in 80x86 family microprocessors. The call to **_disable** prevents the serial port 1 hardware interrupt from being serviced until interrupts are enabled again. If the **Wait_ast** call is made, VTOS enables interrupts for itself as soon as the calling task is blocked. When the call is not made, **_enable** will do the job.

Note that when **Wait_ast** is called, interrupts are still disabled for the calling task after it returns. The **_enable** call is required whether or not **Wait_ast** is called.

Chapter 7 Multitasking

Multitasking is a technique for creating the illusion that two or more programs, or tasks, are running in the same processor at the same time. Actually, the processor executes just one task at a time while the others wait their turn.

VTOS provides facilities for multitasking two or more application tasks in PCMs. This chapter describes multitasking, the reasons for using it, and special considerations which arise when multiple application tasks are running.

Why Use Multitasking?

Multitasking offers a number of benefits:

1. The requirements for an application may contain subsets which are functionally unrelated to each other. Multitasking can provide a clean separation between unrelated requirements. The first example program of chapter 6 illustrates such a task.
2. Multitasking can permit small model code exceeding 64K bytes by partitioning the application into separate tasks. Ideally, the tasks would have no interactions, but this is not always possible. Techniques for communication and data sharing between tasks are described later in this chapter.
3. In some cases, one copy of program code can be executed as two or more tasks performing the same process with different data. For example, a PCM configured for CCM communication on both serial ports executes a single executable file as two tasks. Each task controls just one of the two ports and has its own stack and data segments.

Task Priorities

Every VTOS task has a unique priority, which is related to its task number returned by the VTOS **`Get_task_id`** service. Tasks with larger task numbers have lower priority. Task 0 has the highest priority; it is always assigned to the VTOS Real Time Clock (RTC) task, which manages timers and schedules all other tasks. Task 15 decimal (0F hexadecimal) is the lowest possible priority for application tasks.

VTOS Tasks

In addition to the RTC task, VTOS almost always starts three other system tasks: CPULINK, PCLINK, and OPCOM, although a UCDF configuration from PCOP can suppress them. These tasks are the PLC backplane communication driver task, the PC file transfer task, and the PCM command interpreter task, respectively. In PCM release 3.00 and later, VTOS also starts the remote communication task, REM, whenever a hard reset occurs or when a soft reset occurs and there is no PCMEXEC.BAT file or UCDF in the PCM.

The PCM PT command displays this information when all five VTOS system tasks are active:

```
>pt

0       RTC.COD             RTC.ENV
1       CPULINK.COD         CPU.ENV
2       PCLINK.COD          PCLINK.ENV
3       OPCOM.COD           OPCOM.ENV
4       REM.COD             REM2.ENV

>
```

Each line shows a task number, the executable file name, and the name of an environment block which told VTOS how to run the task.

Task Startup

Multiple PCM application tasks are started using the PCM R (Run) command, in much the same way as for single tasks. However, there is one additional complication. The PCM command interpreter stops accepting input when the first application task starts unless background mode is specified by using the **/B** option. For example:

```
R MYAPP1.EXE /B
R MYAPP2.EXE /B
R MYAPP3.EXE
```

All but the last application task **must** be started in background mode. The final one may also be started in background mode if you need to use PCM commands while the application is running. See "Task Contention for PCM Serial Ports", below, for some issues you must consider when all the application tasks run in background mode, and when two or more tasks share a serial port.

Task Scheduling

VTOS provides two algorithms for scheduling task execution: priority-based and time slice.

Priority-Based Tasks

VTOS priority-based scheduling is conceptually very simple. The highest priority task which is ready to run is given control of the PCM processor. This task continues to execute until it voluntarily gives up control, or a higher priority task becomes ready to run.

A task gives up control unconditionally when it performs WAIT mode I/O or calls one of the VTOS functions **Wait_ast**, **Wait_ef, Wait_gef, Wait_time**, or **Wait_task**. In addition, an executing task gives up control when it calls **Suspend_task** and passes its own task number, or when it calls **Link_sem** or **Block_sem** and the semaphore is busy.

By default, the PCM R (Run) command executes VTOS tasks using priority-based scheduling.

Time-Slice Tasks

Time-slice task scheduling is a bit more complex. Basically, two or more tasks must be explicitly started as time-slice tasks by using the **/E2** or **/T** option, or both, of the PCM R (Run) command. Each time-slice task will execute for the number of milliseconds specified with the **/T** option, or for the default 10 millisecond time slice if the **/E2** option is used alone. At the end of its time slice, the task is suspended, and control is passed to the next time-slice task in the sequence. When all the time-slice tasks have executed once, the first one is resumed again and executes for its allotted time slice. Time-slice tasks execute in ascending order of their task numbers, regardless of the order in which they were started.

The program SLICE.C, shown below, can be used to experiment with time-slice tasks. It simply prints its task number and then wastes time in a counting loop. This process is repeated forever. The number of times the counting loop repeats before printing the task number can be specified as a command line parameter.

```
/* SLICE.C */
#include <vtos.h>
#include <stdio.h>
#include <stdlib.h>

void main(int argc, char far* far argv [])
{
    word i, max_count;
    word task = Get_task_id();

    if (argc < 2 || (max_count = atoi (argv[1])) == 0)
       max_count = 1024;

    for (;;) {
       printf("%5d", task);
       for (i = 0; i < max_count; ++i)
          ;
    }
}
```

After compiling and linking SLICE.C in small model, assign a 1024 byte stack size to SLICE.EXE with the STKMOD utility. Then load SLICE.EXE to a PCM and run it as four time-slice tasks using the PCM batch file SLICE.BAT.

Part of the TERMF screen display produced by this exercise is shown below. The command line parameter **512** specifies **max_count** for each of the tasks; it was selected for a Series 90-30 PCM. The default count, 1024, is about right for a Series 90-70 PCM.

```
> @slice
R SLICE.EXE /B /I9 /E2 /T25 512
R SLICE.EXE /B /I8 /E2 /T25 512
R SLICE.EXE /B /I7 /E2 /T25 512
R SLICE.EXE /B /I6 /E2 /T25 512

>    8   8   8   9   9   9   6   6   6   7   7   7   8   8   8
 9   9   9   6   6   6   7   7   7   8   8   8   9   9   9   6
 6   6   7   7   7   8   8   8   9   9   9   6   6   6   7   7
 7   8   8   8   9   9   9   6   6   6   7   7   7   8   8   9
 9   9   6   6   6   7   7   7   8   8   8   9   9   9   6   6

   . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
```

The first line of output is the command to execute the batch file SLICE.BAT. The PCM command interpreter echos the commands in SLICE.BAT as they are executed. Task 9 is started first, but before it can begin printing its task number, task 8 is started.

Time-slice scheduling requires at least two tasks, so the time-slice task rotation does not begin until task 8 starts. At that time, task 8 pre-empts task 9 because it has higher priority. But the task rotation has begun before task 7 is started, and tasks 7 and 6 are simply added to the rotation. Task 8 is allowed to execute until the end of its time slice. Task 9 follows task 8; then the first complete task rotation begins with task 6. The printed output shows six complete rotations plus the start of the seventh.

Because all the tasks were run in background mode, the PCM command interpreter can accept more commands while the tasks are running. You can use a PCM K (Kill) command to stop each of the tasks.

Interaction of Priority and Time-Slice Tasks

When both priority and time-slice tasks execute, some complex interactions can occur. These rules apply:

1. Time-slice tasks are pre-empted when a priority-based task with higher priority becomes ready to execute.
2. When a time-slice task is pre-empted, its time slice continues to tick away.
3. When a pre-empted time-slice task's time expires, the task is paused. The next task in the time-slice rotation is resumed, but it will execute only if its priority is higher than the priority-based task which pre-empted the previous task in the time-slice rotation.

Another experiment with SLICE.EXE illustrates these rules. This time, the time-slice tasks are 9, 8, 7, and 5. Task 6 is started as a priority-based task.

```
> @slice2
R SLICE.EXE /B /I9 /E2 /T25 512
R SLICE.EXE /B /I8 /E2 /T25 512
R SLICE.EXE /B /I7 /E2 /T25 512
R SLICE.EXE /B /I6 512
R SLICE.EXE /B /I5 /E2 /T25 512

>    6   6   6   6   5   5   5   6   6   6   7   6   6   8   6
 9   6   6   5   5   5   6   6   6   6   6   6   6   6   6   5
 5   6   6   6   6   6   6   6   6   5   5   5   6   6   6   6
 6   6   6   6   6   9   5   5   5   6   6   6   6   6   6   6
 6   6   5   5   6   6   7   6   6   8   6   6   6   6   5   5
 5   6   6   6   6   6   6   6   6   6   5   5   5   6   6   6
 6   6   6   6   6   6   5   5   5   6   6   6   6   6   6   6
 9   6   6   5   5   5   6   6   6   6   6   6   6   6   6   5
 5   6   6   6   6   8   6   6   6   6   5   5   5   6   7   6

   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
```

We know from the previous example that tasks 9, 8, and 7 start executing in a time-slice rotation. But before any of them can print, they are pre-empted when task 6 is started as a priority-based task.

Task 5 is also started as a time-slice task. Since there are four time-slice tasks with equal times, task 5 is allocated one fourth of the PCM processor time. During the other time slices, task 6 executes most of the time because its priority is higher than any of the other time slice tasks. However, tasks 7, 8, and 9 occasionally manage to print. Why?

The answer involves the PCM implementation of **`printf`**. At the lowest level, **`printf`** makes a WAIT mode call to **`Write_dev`** when it sends characters to a PCM serial port. By default, **`Write_dev`** returns when the serial port begins sending the last character of the output data. Since the **`printf`** format string specifies a field width of five characters for the task numbers, each task waits about four character times whenever it calls **`printf`**. During this time, another task is permitted to execute.

Whenever task 5 waits for serial I/O completion, task 6 executes. But during the time slices for tasks 7, 8, and 9, task 6 usually executes. When task 6 waits for **`printf`**, the lower priority task which owns the current time slice can execute. Eventually, they all get enough execution time to complete one pass through the counting loop and print.

In this example, the execution time actually given to three of the time-slice tasks depends entirely on the number of characters printed by a fourth task! This illustrates how unpredictable the result can be when both time-slice and priority-based tasks are used by a PCM application. Great care is required when designing the task processes and assigning them to VTOS task numbers. These principles should be kept in mind:

1. Priority-based tasks should used for time-critical processing such as handling asynchronous events. They should perform their functions and relinquish the PCM processor as quickly as possible.

2. Time-slice tasks should be assigned a group of contiguous task numbers. All the time slice task numbers should be higher than any priority-based task number. That is, all the time-slice tasks should have lower priority than **any** priority-based task.

Task Contention for PCM Serial Ports

The preceding example also shows that the PCM serial ports will happily accept output data from any number of tasks in any order. Requests from two or more tasks to read serial input data can also be pending at the same time, and the results can be unpredictable. For example, try typing **`R BASIC.EXE /B`** at the PCM command interpreter prompt. Running MegaBasic in background (**`/B`**) mode allows the PCM command interpreter to compete with MegaBasic for serial input. The two tasks become very confused.

Caution

When two or more tasks need to share a serial port, they must provide their own mechanism for assuring that one task at a time owns the port. Otherwise, they will corrupt each other's data.

Note that the PCM file server for the **`PC:`** device also uses serial port 1. If an application task needs to use the file server, all other tasks, including the PCM command interpreter, must be prevented from using port 1. In addition, an application task must not attempt to use the serial port while a PC file transfer is in progress.

The PCM command interpreter is normally disconnected from the programmer port (serial port 1 by default), by running one of the application tasks in foreground; that is, without the **`/B`** option of the R (Run) command. When all the application tasks are run with the **`/B`** option, the command interpreter task must be suspended while an application task is receiving serial input or performing a PC file transfer. The application task must execute this code:

```
Suspend_task(3);
/*
 * Use the serial port.
 */
Resume_task(3);
```

Communication Between Tasks

VTOS tasks can signal each other by using event flags. Event flags simply notify the receiving task that an event has occurred. They carry no information about the event. A task can send signals plus information to another task by using asynchronous traps. Finally, tasks can exchange data through shared memory modules, shared files, or a block of memory reserved by the PCM Y (Set upper memory limit) command. Access to these shared memory resources can be controlled with VTOS semaphores.

Event Flags

Chapter 6 in this manual explains how application tasks can request VTOS to notify them with event flags when timer and I/O events occur. Tasks can also signal each other directly by setting local and global event flags.

SWAP.C is a simple example in which two tasks signal each other using global event flags. Both tasks run the same code; the C source is shown here.

```
/* SWAP.C */
#include <vtos.h>
#include <stdio.h>

#define USER_TASKS      0x07FF

word Task_flags [] = {
    EF_15, EF_14, EF_13, EF_12, EF_11, EF_10, EF_09, EF_08,
    EF_07, EF_06, EF_05, EF_04, EF_03, EF_02, EF_01, EF_00
};

void main()
{
    word active_tasks;
    word other_flag;
    word my_task = Get_task_id();
    word my_flag = Task_flags [my_task];
    printf("task %d:  my_flag = %x\n", my_task, my_flag);

    for (;;) {
/*
 * Do something useful here.
 */
       Reset_gef(my_flag);
       active_tasks = Test_task() & USER_TASKS;
       other_flag = active_tasks & (~my_flag);
       printf("task %d:  other_flag = %x\n", my_task, other_flag);

       if (other_flag) {
       Set_gef(other_flag);
          Wait_gef(my_flag);
       }
    }
}
```

The array, **Task_flags,** is initialized with one event flag constant for each task ID value supported by VTOS. The order in which the flags are assigned to array elements assures that the **my_flag** bit for task 15, for example, is the same bit that **Test_task** returns for task 15. This ordering permits each task to calculate the correct event flag for the other task by masking its own bit in the **Test_task** return value. If the other task has not been started or has terminated, the task which is running will obtain zero for the other task's event flag and will not call **Wait_gef**. Although this method of determining the other task's event flag is not the simplest one possible, it has the advantage of preventing a task from waiting for an event flag which will never be set.

Two tasks are started by a PCM batch file, SWAP.BAT. The contents of the batch file and a portion of the output from the two tasks is shown below. Note that the **my_flag** value which each task prints is equal to the **other_flag** value printed by the other task. Both tasks are run in background mode to permit killing them from TERMF. There is no contention for input characters from the programming port because SWAP does not use serial input.

```
> @swap
R SWAP.EXE /B
R SWAP.EXE /B

> task 14:  my_flag = 2
task 14:  other_flag = 1
task 15:  my_flag = 1
task 15:  other_flag = 2
task 14:  other_flag = 1
task 15:  other_flag = 2
task 14:  other_flag = 1
task 15:  other_flag = 2

 .  .  .  .  .  .  .  .
```

The example above uses global event flags for the rather trivial purpose of switching execution from one task to another. However, it should be obvious how this technique can be adapted for sending any kind of signal between tasks.

Local event flags can also be used for signalling between tasks.

Shared Memory Modules

VTOS shared memory modules provide a mechanism for sharing data between two or more tasks. From the point of view of a VTOS task, memory modules are blocks of PCM memory which are accessed through pointers.

Memory modules may be created using the PCM M (Create a Memory Module) command. The module name and its size in bytes must be specified when the module is created. For example, this command:

```
M MODULE1 6
```

creates a memory module named MODULE1 which contains 6 bytes.

By default, memory modules have no checksum protection. However, the PCM Q (Set Protection Level) command may be used add checksum protection to memory modules, making them read-only modules.

There are two mechanisms for determining the address of a memory module from a PCM application. The VTOS **Get_mod** service returns the **far** address of a memory module specified by name:

```
mod_hdr far* p = Get_mod("MODULE1");
byte far* data_ptr = (byte far* )(p + 1);
```

Note that the module name **must** by specified as upper-case characters. **Get_mod** returns the address of the **mod_hdr** structure at the start of the module. The actual data in the module begins immediately after the module header. The data address may be obtained by C pointer arithmetic as shown in the second line of the code fragment above.

The second mechanism for obtaining a memory module address is the VTOS **modc/modv** mechanism. The **/M** option of the PCM R (Run) command may be used to specify one or more memory modules for a VTOS task. These modules are passed as function parameters of **main**.

The main function of a VTOS program may be declared like this:

void main (int argc, char far* far argv[], int modc, mod_hdr far* far modv[])

where **argc** and **argv** are the conventional C parameters for passing command line arguments to the program. The parameters **modc** and **modv** are unique to VTOS. They provide the count of memory modules specified on the command line and an array of their addresses, respectively. At least one module is passed to every VTOS task; the address of the **arg_blk** structure used to start the task is always in **modv[0]**. When the value of **modc** is 2 or more, additional **modv** elements contain the addresses of memory modules. Unlike **modv[0]**, optional **modv** elements contain the addresses of **mod_hdr** structures.

The example program, MODV.C, prints the addresses of all the memory modules passed to it:

```
/* MODV.C */
#include <vtos.h>
#include <stdio.h>

void main(int argc, char far* far argv[], int modc, mod_hdr far* far modv[])
{
    int i;

    for (i = 0; i < modc; ++i) {
       printf("modv[%d] = %04x:%04x\n", i,
                  *((word far* )&modv[i] + 1), *((word far* )&modv[i]));
    }
}
```

Here is another example which shows how two VTOS tasks may share a memory module. The example comprises four files: MODULE.BAT, MODULE.H, T1.C, and T2.C.

MODULE.H defines two global event flags, the name of a shared memory module, and the structure type of the data in the shared module. All but the module name will be used by both application tasks.

```
/* MODULE.H */
#define DATA_READY_GEF        EF_00
#define EXIT_GEF              EF_01
#define APP_MODULE            "MODULE1"

 typedef struct {
    word task_num;
    char far* s;
 } mod_data;
```

T1.C includes MODULE.H. It uses the module name defined as APP_MODULE to get the module address from **Get_mod**. If the module exists, T1 writes values to the **task_num** and **s** members of its data structure. Then it resets global event flag EXIT_GEF, sets DATA_READY_GEF, and waits for EXIT_GEF to be set. This event flag signals that the data in the **str** array in T1's stack segment is no longer needed. T1 can exit, returning its stack and data segments to VTOS free memory.

```
/* T1.C */
#include <vtos.h>
#include <stdio.h>
#include "module.h"

mod_hdr far* mod_p;               /* defined in VTOS.H */
mod_data far* mod_data_p;       /* defined in MODULE.H */

void main()
{
    word task = Get_task_id();
    char str[40];

    sprintf(str, "Hello from T1 running as task %d\n", task);
    mod_p = Get_mod(APP_MODULE);

    if (mod_p != NULL) {
       printf("task T1: module found: module address = %04x:%04x\n",
               *((word* )&mod_p + 1), *((word* )&mod_p));
       mod_data_p = (mod_data far* )(mod_p + 1);
       printf("                  module data address = %04x:%04x\n",
               *((word* )&mod_data_p + 1), *((word* )&mod_data_p));

       mod_data_p->task_num = task;
       mod_data_p->s = str;

       printf("module data = %04x %04x %04x\n",
               *((word far* )mod_data_p),
               *((word far* )mod_data_p + 1),
               *((word far* )mod_data_p + 2));

       Reset_gef(EXIT_GEF);
       Set_gef(DATA_READY_GEF);
       Wait_gef(EXIT_GEF);
    }
}
```

T2.C also includes MODULE.H, but it finds the address of MODULE1 from **modv[1]**. T2 waits for T1 to set DATA_READY_GEF, indicating that the shared module data has been initialized. T2 then accesses and prints the data.

```
/* T2.C */
#include <vtos.h>
#include <stdio.h>
#include "module.h"

mod_data far* mod_data_p;       /* defined in MODULE.H */

void main(int argc, char far* far argv[], int modc, mod_hdr far* far modv[])
{
    if (modc < 2) {
       printf("\ntask T2: memory module not found\n");
       return;
    }
    Reset_gef(DATA_READY_GEF);
    Wait_gef(DATA_READY_GEF);
    mod_data_p = (mod_data far* )(modv[1] + 1);

    printf("\ntask T2: module data address = %04x:%04x\n",
               *((word* )&mod_data_p + 1), *((word* )&mod_data_p));

    printf("module data = %04x %04x %04x, task_num = %d, string = \"%s\"\n",
       *(word far* )mod_data_p,
       *((word far* )mod_data_p + 1),
       *((word far* )mod_data_p + 2),
       mod_data_p->task_num,
       mod_data_p->s);

    Set_gef(EXIT_GEF);
}
```

Here is the output which TERMF displays when the two tasks are run from the PCM batch file MODULE.BAT. The shared module is created here.

```
> @module
M MODULE1 6
R T2.EXE /I0E /MMODULE1 /B
R T1.EXE /I0F
task T1: module found: module address = 0296:0000
                module data address = 0296:0020
module data = 000f 03a8 0fd0

task T2: module data address = 0296:0020
module data: task_num = 15, string = "Hello from T1 running as task 15"

>
```

Creating Memory Modules From Applications

Memory modules may also be created by PCM applications, as shown in this code fragment:

```
word task_id = Get_task_id();
word handle = Open_dev("RAM:MODULE2", WRITE_MODE, WAIT, task_id);
Seek_dev(handle, SIZE, WAIT, task_id);
Close_dev(handle, WAIT, task_id);
```

where SIZE is the desired memory module size in bytes. However, this method is **not** equivalent to the PCM M command.

1. The **Open_dev** call creates only a module header; that is, a structure of type **mod_hdr**, as defined in VTOS.H. The **Seek_dev** call creates another memory module, which is linked to the first. The size of the new module is the smallest integer multiple of 1024 bytes which is larger than SIZE.
2. If a **Seek_dev** call is made which specifies a position beyond the end of the last data module, a new memory module will be created and linked to the end of the module chain.
3. This method, unlike the PCM M command, does not fill the new module with zeros. Additional code would be needed to do so.

The only reliable way to find the data address of a module created with this method is shown in the example program, MODTEST.C. It creates a new file named MYMODULE in the RAM: device. Then, two **Seek_dev** calls are made to extend the module length. Finally, the linked list of modules which make up the file is traversed.

```
/* MODTEST.C */
#include <vtos.h>
#include <stdio.h>

#define SIZE1 128
#define SIZE2 1992

mod_hdr far* mod_p;

void main()
{
    long unsigned data_size = 0;
    word task = Get_task_id();
    word handle = Open_dev("RAM:MYMODULE", WRITE_MODE, WAIT, task);
    Seek_dev(handle, SIZE1, WAIT, task);
    Seek_dev(handle, SIZE2, WAIT, task);
    Close_dev(handle, WAIT, task);

    mod_p = (mod_hdr far* )Get_mod("MYMODULE");
    for (;;) {
       data_size += mod_p->modsize;
       printf("module name     = %s\n", (char far* )mod_p->name);
       printf("module size     = %ld\n", mod_p->modsize);
       printf("module alias    = %04x\n", mod_p->modalias);

       if (mod_p->modtype & LAST_MOD) {
          data_size -= mod_p->modalias;
          break;
       }
       *((word far*)&mod_p + 1) = mod_p->modalias;
    }
    printf("\ntotal data size = %ld bytes\n", data_size);
}
```

Note that the device name, RAM:, is **required** in the string passed to **Open_dev**, but may not be included in the string passed to **Get_mod**.

Running MODTEST produces this output:

```
> r modtest.exe

module name        = MYMODULE
module size        = 0
module alias       = 1c09

module name        = MYMODUL.001
module size        = 1024
module alias       = 1c4c

module name        = MYMODUL.002
module size        = 1024
module alias       = 0038

total data size    = 1992 bytes

>
```

MYMODULE contains three distinct memory modules, but only MYMODUL.001 and MYMODUL.002 contain data. As before, the data address within these modules is (**mod_p + 1**).

Note

When the **Open_dev/Seek_dev** method is used to create a memory module, just one **Seek_dev** call should be made. The position passed to **Seek_dev** should be as large as the maximum data size the module will ever need.

Asynchronous Traps

Chapter 6 also describes the use of ASTs for handling asynchronous events. ASTs can be used for communication between tasks, as well. Here is an example program in which two tasks exchange signals and data with ASTs. There are three files: AST.H, AST1.C, and AST2.C.

In order to send an AST to the other task, each one must have two items of information: the target task number and the address of an AST function. These items are passed in a shared memory module, MODULE2. The **mod_data** structure in AST.H specifies the data in the module.

```
/* AST.H */
#define READY_1_GEF        EF_00
#define READY_2_GEF        EF_01
#define MOD_NAME           "MODULE2"

typedef struct {
    word task1_num;
    word task2_num;
    void(far* tmr_ast_func)();
    void(far* post_ast_func)();
} mod_data;
```

AST1.C contains an AST function, **ast_func**, which simply prints the task name and the values of the **ast_blk** members which its parameter points to. The **main**

function also prints the task name. In addition, **main** resets the global event flags READY_1_GEF and READY_2_GEF, and then waits for AST2 to set READY_2_GEF.

After READY_2_GEF is set, signalling that AST2 has completed its part of the shared module initialization, AST1 initializes its data in the module, starts a timer, prints the timer handle and then waits for an AST. After the AST is processed, AST1 exits from **main**.

The **Start_timer** call from AST1 specifies that AST2 should be notified with an AST when the timer expires. The **task2_num** and **tmr_ast_func** members from the shared module data are used to specify the task and AST function, respectively. AST1 uses its own task number as the handle value which will be passed to the AST function.

```
/* AST1.C */
#include <vtos.h>
#include <stdio.h>
#include "ast.h"

mod_data far* p;
mod_hdr far* mod_ptr;

void far ast_func(ast_blk far* p)
{
    printf("task AST1: an AST was posted:\n");
    printf("  handle = %04x\n", p->handle);
    printf("  arg1   = %04x\n", p->arg1);
    printf("  arg2   = %04x\n", p->arg2);
    printf("  arg3   = %04x\n", p->arg3);
    printf("  arg4   = %04x\n", p->arg4);
}

void main()
{
    word tmr_hndl;
    word task = Get_task_id();

    printf("task AST1: id = %d\n", task);
    Reset_gef(READY_1_GEF | READY_2_GEF);
    Wait_gef(READY_2_GEF);
/*
 * The other task has initialized its data in the module.
 */
    mod_ptr = Get_mod(MOD_NAME);
    p = (mod_data far* )(mod_ptr + 1);
    p->task1_num = task;
    p->post_ast_func = ast_func;
/*
 * Start a timer which will notify the other task by posting an AST.
 */
    tmr_hndl = Start_timer (
       AST_NOTIFY_MODE | TASK_SPECIFIED | RELATIVE_TIMEOUT | p->task2_num,
       MS_COUNT_MODE, 0, 1000, p->tmr_ast_func, task);

    printf("task AST1: timer handle = %04x\n", tmr_hndl);
    Set_gef(READY_1_GEF);

    Wait_ast();
}
```

AST2 also contains an AST function, **timer_ast_function**. It is the function which was specified by AST1 when it started the timer. This AST function prints the members of its **ast_blk**.

The **main** function of AST2 assumes that it can begin initializing MODULE2 when it begins execution. It copies task and AST function address values to its members of the shared module, signals AST1 by setting READY_2_GEF, and then waits for READY_1_GEF. When the **Wait_gef** call returns, signaling that AST1 has completed its initialization, AST2 posts an AST to AST1 and then waits for its timer AST to occur. AST2 exits after the timer AST is processed.

```
/* AST2.C */
#include <vtos.h>
#include <stdio.h>
#include "ast.h"

mod_data far* p;
mod_hdr far* mod_ptr;

void far timer_ast_function(ast_blk far* p)
{
    printf("task AST2: a timer AST occurred:\n");
    printf("  handle = %04x\n", p->handle);
    printf("  arg1   = %04x\n", p->arg1);
    printf("  arg2   = %04x\n", p->arg2);
    printf("  arg3   = %04x\n", p->arg3);
    printf("  arg4   = %04x\n", p->arg4);
}

void main()
{
    word task = Get_task_id();

    printf("task AST2: id = %d\n", task);
    mod_ptr = Get_mod(MOD_NAME);
    p = (mod_data far* )(mod_ptr + 1);
    p->task2_num = task;
    p->tmr_ast_func = timer_ast_function;
    Set_gef(READY_2_GEF);
    Wait_gef(READY_1_GEF);

    Post_ast(p->task1_num, p->post_ast_func, task, 1, 2, 3, 4);
    Wait_ast();
}
```

Since AST1 resets the global event flags which control the initialization of MODULE2, it must be run first and at higher priority than AST2. The PCM batch file, AST.BAT, allocates MODULE2 and then runs the two tasks in the correct order.

```
> @ast
M MODULE2 0C
R AST1.EXE /I0E /B
R AST2.EXE /I0F
task AST1: id = 14
task AST2: id = 15
task AST1: timer handle = 3903
task AST1: an AST was posted:
    handle = 000f
    arg1   = 0001
    arg2   = 0002
    arg3   = 0003
    arg4   = 0004
task AST2: a timer AST occurred:
    handle = 000e
    arg1   = 0078
    arg2   = 5a3f
    arg3   = e55e
    arg4   = 0002

>
```

Note that the **ast_blk** members **arg1** through **arg4,** printed by **timer_ast_function**, contain strange values. For timer AST functions, only the **handle** member can be specified.

Semaphores

In some situations, memory modules must be accessed repeatedly by two or more tasks. When these accesses occur asynchronously, semaphores provide a convenient mechanism for preventing access conflicts. This example shows how access to a shared module may be controlled by a semaphore. This example also uses three source files.

File SEM.H defines a new **mod_data** structure type for the memory module, as well as string constants for the module and semaphore names. In addition, there are constant values for the module size and **access_flag** member of the structure.

```
/* SEM.H */
#define SEM_NAME          ”MOD_SEM”
#define MOD_NAME          ”MODULE3”
#define MOD_SIZE          512

typedef struct {
    word access_flag;
    char s[MOD_SIZE – sizeof(word)];
} mod_data;

/* access_flag values */
#define FREE              0
#define BUSY              1
#define DIRTY             2
```

Task SEM1 gets a wait time value from its command line parameter. Then it assigns the module data address to **p**, which is declared as a **far** pointer to **mod_data**. Finally, it links to the semaphore and enters a non-terminating loop.

At the top of the loop, SEM1 has acquired control of the semaphore. It tests the **access_flag** member of **mod_data**. If the module data area is FREE, SEM1 calls **sprintf** to construct a string and copy it to the memory module, and then sets the access flag to DIRTY, indicating that the data contains a new value. Note that both of these operations are protected by the semaphore. Since **sprintf** makes no VTOS service requests, it may be called safely from semaphore-protected code.

SEM1 releases the semaphore and then waits for for the time which was specified on the command line (if any) or the default value. After the delay, SEM1 attempts to acquire the semaphore again before repeating the loop. If some other task happens to control the semaphore, SEM1 will not execute until all the tasks ahead of it at the semaphore have had their turn.

```
/* SEM1.C */
#include <vtos.h>
#include <stdio.h>
#include "sem.h"

void main(int argc, char far* far argv[])
{
    mod_hdr far* mod_ptr;
    mod_data far* p;
    word sem_hndl, wait_time;
    word count = 0;
    word task = Get_task_id();

    if (argc < 2 || (wait_time = atoi (argv[1])) == 0)
       wait_time = 10;
    printf("task SEM1: id = %d, wait time = %d\n", task, wait_time);
    mod_ptr = Get_mod(MOD_NAME);
    p = (mod_data far* )(mod_ptr + 1);
    sem_hndl = Link_sem (SEM_NAME);

    for (;;) {
       if (p->access_flag == FREE) {
          sprintf(p->s, "Hello from task %d: count = %d", task, count++);
          p->access_flag = DIRTY;
       }
       Unblock_sem(sem_hndl);
       Wait_time(MS_COUNT_MODE, 0, wait_time);
       Block_sem(sem_hndl);
    }
}
```

Task SEM2 also gets a delay value from its command line, assigns the module data address to a pointer, and links to the same semaphore. When it acquires the semaphore, it enters its own **for** loop.

In the loop, SEM2 tests the **access_flag** in the module data to determine whether there is new (that is, DIRTY) data. If so, the module is marked BUSY. Next, SEM2 releases the semaphore before calling **printf**. The call must not be made within semaphore-protected code, because printf makes a VTOS request to write the data to SEM2's STDIO device. However, the BUSY value of the access flag prevents other tasks from writing new data to the module.

After printf returns, SEM2 re-acquires the semaphore and changes the access flag value to FREE. Then it releases the semaphore and waits before trying to acquire it again.

```
/* SEM2.C */
#include <vtos.h>
#include <stdio.h>
#include <string.h>
#include "sem.h"

void main(int argc, char far* far argv[])
{
    mod_hdr far* mod_ptr;
    mod_data far* p;
    word sem_hndl, wait_time;
    word task = Get_task_id();

    if (argc < 2 || (wait_time = atoi (argv[1])) == 0)
       wait_time = 2;
    printf("task SEM2: id = %d, wait time = %d\n", task, wait_time);
    mod_ptr = Get_mod(MOD_NAME);
    p = (mod_data far* )(mod_ptr + 1);
    sem_hndl = Link_sem(SEM_NAME);

    for (;;) {
       if (p->access_flag == DIRTY) {
          p->access_flag = BUSY;
          Unblock_sem(sem_hndl);
          printf("task %d says, \"%s\"\n", task, p->s);
          Block_sem(sem_hndl);
          p->access_flag = FREE;
       }
          Unblock_sem(sem_hndl);
          Wait_time(MS_COUNT_MODE, 0, wait_time);
          Block_sem(sem_hndl);
    }
}
```

The batch file SEM.BAT starts one task using SEM2.EXE and two tasks using SEM1.EXE. Before starting the two tasks, SEM.BAT deletes the existing copy of the shared module, if there is one, and creates a new copy which VTOS initializes to contain zero character values.

A portion of the output from a Series 90-30 PCM is shown below. Note that using an access flag in the memory module assures that SEM2 will always print each distinct data string exactly once. In addition, each of the two SEM1 tasks uses every count value, starting at 0, exactly once. The frequency with which the two SEM1 tasks are able to access the shared memory module is controlled by the delay time values specified in their command lines.

```
> @sem
X MODULE3
M MODULE3 200
R SEM2.EXE 1 /B
R SEM1.EXE 3 /B
R SEM1.EXE 10
task SEM1: id = 13, wait time = 10
task SEM1: id = 14, wait time = 3
task SEM2: id = 15, wait time = 1
task 15 says, "Hello from task 13: count = 0"
task 15 says, "Hello from task 14: count = 0"
task 15 says, "Hello from task 13: count = 1"
task 15 says, "Hello from task 13: count = 2"
task 15 says, "Hello from task 14: count = 1"
task 15 says, "Hello from task 14: count = 2"
task 15 says, "Hello from task 14: count = 3"
task 15 says, "Hello from task 14: count = 4"
task 15 says, "Hello from task 14: count = 5"
task 15 says, "Hello from task 13: count = 3"
task 15 says, "Hello from task 14: count = 6"
task 15 says, "Hello from task 13: count = 4"
task 15 says, "Hello from task 14: count = 7"
task 15 says, "Hello from task 14: count = 8"
task 15 says, "Hello from task 13: count = 5"
task 15 says, "Hello from task 14: count = 9"
task 15 says, "Hello from task 13: count = 6"
task 15 says, "Hello from task 14: count = 10"
task 15 says, "Hello from task 14: count = 11"
task 15 says, "Hello from task 13: count = 7"
task 15 says, "Hello from task 14: count = 12"

  .   .   .   .   .   .   .   .   .   .   .
```

Caution

VTOS function calls must <u>not</u> be made, directly or indirectly, from code which is executed after a `Link_sem` or `Block_sem` call and before an `Unblock_sem` call. Violating this rule can cause a PCM application to lock up.

All standard C library functions which perform data input or output operations (such as `getc`, `fputs` and `printf`) use VTOS I/O services. These functions must not be called within semaphore-protected code.

Debugging Multiple Tasks

Applications with multiple tasks can be debugged with the same techniques which are used for single tasks. However, there are some additional considerations.

The sequence of events is often harder to understand when events are handled by different tasks. Keeping a trace history with information from all the application tasks can help a great deal. The trace can be kept in a shared memory module with access controlled by a semaphore, as shown in the preceding section.

Dumping PCM Task State Information

Several kinds of problems which occur commonly during the development phase of multiple task PCM applications can be diagnosed by looking at task state information. You can take a ''snapshot'' of the states of all the active tasks in a PCM and then analyze the state data. Whenever a PCM soft reset occurs (holding the reset / restart pushbutton down for less than five seconds), the states of all the VTOS tasks and a portion of each task's stack are saved. When you execute the PCM PD (Dump the PCM task status) command from TERMF, the data saved during the most recent soft reset is sent to a file named PCMDUMP.OUT in the current PC disk drive and directory. PCMDUMP.OUT is a binary file. The PCMDUMP.EXE utility, furnished with the PCM C toolkit, formats the binary task data into readable form.

When a PCM is configured to start an application on soft resets, a hard reset (holding the button down for ten seconds) may be required to access the PCM command interpreter. Hard resets have no effect on the task state and stack data from the most recent soft reset. However, cycling PLC power off and on will corrupt any state data which was previously saved.

The task state data makes it easy to diagnose common problems which are otherwise very difficult. For example, it is obvious when a task is waiting for an AST with ASTs disabled. If you run an application several times and same task is always executing at the same code location (CS:IP register values), the task may be stuck in a loop.

For complete information on dumping PCM task state information and using the PCMDUMP utility, see chapter 11, *Utilities*.

Using In-Circuit Emulators

Complex interactions between application tasks and asynchronous events often lead to software errors which are difficult to diagnose. In-circuit emulators offer a unique capability which can often be invaluable – an execution trace history collected by the hardware. Solving software problems often requires knowing how the code reached a particular point, and in-circuit emulators provide this information without special trace code. Their cost is frequently justified by improvements in productivity and time to market.

Using an in-circuit emulator requires a correlation between code and data addresses in the map of the EXE file and the corresponding addresses in PCM memory. The technique described in the previous section is also applicable to in-circuit emulators.

Chapter 8 Memory Models

The segmented architecture of the Intel 80x86 family of microprocessors gives rise to several different memory or compilation models. These models are nothing more than alternate views of the segmented architecture. Each model offers a different tradeoff between code speed and size, on one hand, and restrictions on code and data sizes, on the other. This chapter discusses the memory models supported by the PCM and their implications for developing PCM C applications.

Models Supported By the PCM

VTOS supports the small, medium and large memory models. Each is discussed below.

Small Model

In the small model, the code, data, and stack segment registers of the microprocessor are loaded by VTOS when the application starts. By default, function calls are intra-segment (**near**) calls, static data references are within the single data segment (**near** data), and pointers to data are **near** pointers. The segment registers are never changed by the task's code unless the programmer intentionally overrides the default behavior. Consequently, compiling in small model produces code which is somewhat smaller and faster than with the other models.

The tradeoff for this efficiency is a size limitation for both code and data. Each task is limited to 64K bytes of code and 64K bytes of static data.

Medium Model

In medium model, function calls are inter-segment (**far**) calls by default. This removes the 64K byte code size limitation at a cost of two extra code bytes per function call. There is also a speed penalty. In Series 90-70 PCMs, the total call and return time for each function call is a bit more than one microsecond longer than for small model. In Series 90-30 PCMs, the penalty is almost two microseconds.

Data pointers and references are **near** by default in medium model.

Large Model

Large model overcomes the 64K byte static data size limitation of the small and medium models. The total size of constants and initialized variables is 64K bytes, but each C source file may also have its own uninitialized data segment. These may be as large as 64K bytes each. Large model adds still more code for function calls and returns, and **far** accesses are required for data in the uninitialized data segments. Pointers to data are **far** by default. The **far** data accesses and pointers require extra code and time to load microprocessor segment registers. Consequently, large model has the largest code size and slowest execution of any memory model supported by PCMs.

Small and Medium Model Differences Between VTOS and MS-DOS

Unlike MS-DOS, VTOS assigns different data and stack segments to small and medium model tasks. One benefit is that tasks using these models can have up to 64K bytes of static data plus 64K bytes of automatic (stack) data. However, there is a cost to PCM C programmers:

1. Pointers to data must be declared **far** if they will ever contain the address of an automatic (stack-based) variable, or any other address outside the task's data segment, when passed as a function parameter. The safest practice is to declare all pointers to data as far pointers. For example:

```
/* TEST1.C */
#include <vtos.h>
#include <string.h>
#include <stdio.h>

void main( void )
    {
    char text[] = "PCM C";
    char far* p;                                    /* MUST be far */

    for ( p = text; *p != 'M'; ++p )
       ;

    printf( "%d\n", strlen ( p ) );
    }
```

In this example, the pointer, **p**, is assigned the address of an automatic array, **text,** in the for loop initializer. The address in **p** is modified and then passed to the standard C library function **strlen**. Note that Microsoft C 6.0 produces a warning message when it uses the address of a stack-based variable in line 8 of this example, where the string constant is copied to **text**. In this case, the warning does not indicate a problem:

```
warning C4058: address of automatic (local) variable taken, DS != SS
```

Try running this program yourself, to verify that it works. It prints the expected result, 3. Then, change the declaration of **p** to just **char*** and try it again. This time, the same warning is also produced at line 11. The program prints 5, which is clearly an error. The second warning message **does** indicate a problem. You can examine the TEST1.COD file to find out why.

2. All function parameters which are addresses have been declared **far** in the function prototypes in VTOS.H, the PLC API header files, and the PCM C toolkit header files for standard C library functions. However, a few functions accept a variable number of parameters and / or parameters of varying type. The function prototypes for these functions contain an ellipsis (...) where parameters may vary. All addresses passed as variable parameters in the small or medium memory models must be either identifiers which have been declared as **far** pointers or explicitly type cast to **far***.

There are two commonly used families of library functions with variable parameter lists: the VTOS device services (**Open_dev**, etc.) and the **printf** family of standard C library functions. This example shows how to print strings using **printf** in small model:

```
/* TEST2.C */
#include <vtos.h>
#include <string.h>
#include <stdio.h>

char str[] = "PCM";
char s[4];

void main( void )
    {
    char far* p = s;
    strcpy( p, "C" );
    printf( "%s %s %s\n", (char far* )str, p, (char far* )"toolkit" );
    }
```

The **printf** call in this example has three optional parameters, all pointer to **char**. The second one, **p**, was declared **far***, and does not need a type cast. However, the array, **str**, and the string literal, **"toolkit"**, are passed by default as **near** addresses. They **do** need type casts.

For information on using optional parameters in VTOS device services, see "DeviceI / O Functions" in chapter 5, *PCM Libraries and Header Files.*

Advantages and Restrictions

Each memory model supported by VTOS has its own set of advantages and restrictions. They are summarized below.

Small Model:

- Smallest, fastest code of any memory model supported by VTOS.
- Code size is limited to 64K bytes maximum.
- Constant and static data are limited to 64K bytes total, all of which must be in DGROUP.
- Automatic (stack) data is limited to 64K bytes total.
- Two or more tasks can execute a single copy of code; each task has its own data and stack.
- Static data may be initialized in declarations; VTOS initializes it every time the task runs.
- PROMable.

Medium Model:

- Code is almost as small and fast as small model.
- Code size is limited only by PCM RAM or PROM size.
- Constant and static data are limited to 64K bytes total, all of which must be in DGROUP.
- Automatic (stack) data is limited to 64K bytes total.
- Two or more tasks can execute a single copy of code; each task has its own data and stack.
- Static data may be initialized in declarations; VTOS initializes it every time the task runs.
- PROMable (up to about 128K bytes of code and initialized data).

Large Model:

- Large model applications may not contain initialized data that changes during execution. The Microsoft linker places initialized data into an area that is protected by a checksum when the executable file is loaded to the PCM. Executing the application causes the data to change. At the next module reset, the checksum test of the application will fail, causing the PCM to delete it from memory.

  For large model, only data that is declared **`const`** should be assigned initial values. All othert data must be initialized by assignment statements.

- Code is larger and slower than any other memory model supported by VTOS.
- Code size is limited only by PCM RAM or PROM size.
- Constant data is limited to 64K bytes total, but uninitialized static data is limited only by PCM RAM size.
- Automatic (stack) data is limited to 64K bytes total.
- Constants and other initialized data are initialized only once, when the task is loaded. When initialized data is modified by the application, VTOS is unable to reset it to its initial values after the application runs the first time. Consequently, the application itself must initialize any data which it modifies.
- Code is not PROMable.

Making the Most of Small and Medium Models

In small model, the 64K byte code size restriction can often be circumvented by partitioning an application into two or more tasks. See chapter 7, *Multitasking,* for details.

In small and medium models, the 64 Kbyte limitation on static data can almost always be avoided by allocating free PCM memory for large data structures and arrays. These structures and arrays are then accessed through **`far`** pointer variables. Microsoft C 6.0 actually generates more code bytes to access a structure member or array element in a large model **`far`** data segment than through a **`far`** pointer in medium model!

Chapter 9 Example Programs

This chapter describes an example PCM application that demonstrates how to use PCM and VTOS capabilities in actual applications. The example consists of three PCM C programs and a PLC ladder logic program. The PCM programs execute as separate PCM tasks. They exchange data with the PLC program and an operator interface terminal (OIT) connected to the PCM.

Serial port 1 of the PCM is reserved for the programming computer; you can query the PCM command interpreter while the application runs.

All the files required to compile and link the three PCM tasks, and to load them to a PCM and execute them, were copied to the \PCMC\EXAMPLES\DEMO_3T directory on your PC when you installed the PCM C toolkit. In addition, the PLC ladder program that cooperates with the PCM tasks is provided in separate Logicmaster 90 program folders for Series 90-30 and Series 90-70 PLCs. These folders are \PCMC\EXAMPLES\DEMO_3T\PLC_30 and \PCMC\EXAMPLES\DEMO_3T\PLC_70, respectively.

PLC Hardware Requirements

The demo will run in a Series 90-70 PCM with any (or no) memory expansion board. A Series 90-30 PCM 301 or PCM 311 is required in order to configure serial port 2 for RS-232C operation with the OIT. Our OIT was a VT100 from Digital Equipment Corp. If you have an RS-422 / RS-485 terminal, you can use a PCM 300.

Logicmaster 90 Compatibility

The Logicmaster program folders were created using version 2.04 of Logicmaster 90-30 and version 3.04 of Logicmaster 90-70. If you have one of these versions or a later one, you can select the appropriate folder directly from the Logicmaster Programmer and Configurator packages.

If you have an earlier Logicmaster version, such as a Release 2 version of Logicmaster 90-70, you will not be able to select the PLC program folder. You can print the text file version of the program for your PLC, PLC_30.PRT or PLC_70.PRT, in the \PCMC\EXAMPLES\DEMP_3T directory, and then enter the program manually into the Logicmaster 90 Programmer.

Logicmaster 90-30 Configuration

The Logicmaster 90-30 I/O configuration specifies a PCM 301. You will need to change the I/O configuration in the Logicmaster 90-30 folder, \PCMC\EXAMPLES\DEMO_3T\PLC_30, if you use a different Series 90-30 PCM model.

The Series 90-70 PCM can run the demo without a Logicmaster 90-70 I/O configuration, and none is provided in the Logicmaster 90-70 folder.

PCM Rack and Slot Location

The PLC ladder programs assume that the PCM is installed in PLC rack 0, slot 2. If your PCM is in a different location, you will need to change the SYSID input to the COMMREQ function blocks in the program. If you use a Series 90-30 PLC, you will also need to change the PCM slot location in the I/O configuration for your PLC.

Building The PCM Executable Files

Follow these steps to build the PCM files:

1. Make the hard drive where the PCM C toolkit is installed the current drive. Make \PCMC\EXAMPLES\DEMO_3Tthecurrent directory.

2. Type:

```
nmake mk_demo3
```

or

```
nmk mk_demo3
```

as appropriate (See, ‘‘Using Makefiles’’ in chapter 3 of this manual.), followed by the Enter key at the MS-DOS prompt. The Microsoft NMK or NMAKE utility will compile all the sources, link the three executable files, and set the stack sizes.

3. Run TERMF on your computer.

4. At the PCM command prompt, type: **`l load.bat`** and press the Enter key.

5. Then, type: **`@load`** at the PCM command prompt and press the Enter key. The PCM commands in LOAD.BAT will load the application files to the PCM.

6. Exit from TERMF by holding the Ctrl key down while pressing the Break key.

7. Start the Logicmaster 90 software on your PC. Select the PLC folder that is appropriate for your PLC. If you are using a Series 90-30 PLC, load configuration and logic to the PLC; otherwise, load just logic.

   Note that the rung numbers the Logicmaster software displays for the comment rungs of the PLC program may vary from the rung numbers shown in Listing 9.1, depending on your version of Logicmaster 90 software.

8. Put the PLC CPU into RUN mode and reset the PCM by pressing the Restart/Reset pushbutton for less than five seconds. Use Logicmaster 90 software to trigger PCM COMMREQs by toggling %M0001 and %M0021. Change the value of %R0050 to trigger activity on the OIT. For details on the operation of the demo, see the following sections and comments in the PLC program and C source files.

The PCM Tasks

Three PCM tasks are included in the demo: TASK1, TASK2, and DATA. Detailed descriptions for them can be found in the following sections.

Each task contains debugging code that is compiled only when the DEBUG macro symbol is defined. This debug code sends text messages to the VTOS device named by the DEBUG_DEV macro definition. DEBUG_DEV is opened and written as a file, using the **`fopen`** and **`fprintf`** library functions, respectively. The source files define DEBUG_DEV to be **`com1:`**.

The makefile for this application, MK_DEMO3, uses the Microsoft C command line option /D to define the DEBUG C preprocessor macro. An NMK or NMAKE macro, also named DEBUG, specifies that either "/DDEBUG" or no characters at all are inserted into compiler command lines when the DEBUG macro is evaluated.

TASK1

The C source code for the first of the PCM tasks that comprise the demo application is in the file \PCMC\EXAMPLES\DEMO_3T\TASK1.C. This task shares a memory module with TASK2.C; the module contains data, flags, and asynchronous trap (AST) addresses. When PCMEXEC.BAT starts the application, it clears the memory module and passes it to each task.

In operation, TASK1 periodically reads a register (%R) value from the CPU. If the new value is different from the previous value, an AST is posted to TASK2 using the AST address and task ID values that TASK2 previously stored in the shared memory module. The new register value is passed to TASK2's AST function as a member of an **`ast_blk`** structure.

A VTOS timer controls the time between register read operations. When the timer expires, the function **`tmr_ast`** is called to read the CPU data, make the comparison, and, when appropriate, post the AST to TASK2.

TASK1 also receives ASTs from TASK2. The function **`other_task_ast`**, imported from TASK_AST.C, processes these ASTs; it is described below.

The **`main`** function of TASK1 finds the data address of the shared memory module. If the module name was not specified on TASK1's command line, it prints an error message and exits immediately.

If TASK1 was compiled with DEBUG defined, **`main`** opens the debug device and writes a debug message announcing its task name, task number, and the shared module data address.

Next, **`main`** links to the SEM_NAME semaphore. When it has acquired the semaphore, **`main`** initializes its own AST function address and task number variables in the shared module, clears the port allocation flag, and releases the semaphore.

After waiting for one second to give the PCM and PLC CPU time to begin communication, **main** opens two I/O channels on the CPU: device – one for reading PLC register data, starting at %R00050, and the other for writing register data, starting at %R00060. If VTOS is unable to open either of these channels, **main** exits immediately.

Finally, **main** posts an AST to itself to start the periodic reading of PLC register values. Then it enters a non-terminating loop to wait for ASTs. In the loop, timer ASTs and ASTs posted by TASK 2 are processed in the order in which the events occur.

TASK2

TASK2 is similar to TASK1. Its source is \PCMC\EXAMPLES\DEMO_3T\TASK2.C. TASK2 receives COMMREQ messages from the PLC CPU. When a COMMREQ arrives, it is processed by the function **commreq_ast**, which sends one data word from the COMMREQ to TASK1 by posting an AST. The AST includes the COMMREQ data. It is posted using the AST address and task ID information that TASK1 previously stored in the shared memory module.

TASK2 also imports **other_task_ast** from TASK_AST.C to process ASTs it receives from TASK1.

The **main** function of TASK2 performs initialization in much the same way as TASK1. Before entering its loop, **main** calls **Read_dev** in AST_NOTIFY mode so that **commreq_ast** will be called when the first COMMREQ arrives.

TASK_AST.C

This source file contains the function **other_task_ast**; it is linked into both TASK1 and TASK2. The function name derives from its use; each copy of the function processes ASTs from the other task.

When TASK1 or TASK2 posts an ast to the other task, VTOS calls **other_task_ast** in the target task. The **ast_ptr** parameter points to an **ast_blk** structure that contains a data value sent from the other task. The function displays the data value on the OIT, prompts the user to enter a new value, and then waits for user input. Only decimal digits, the destructive backspace, and the Return/Enter character are accepted as input; all other characters are rejected. Each backspace character erases the digit character that is immediately to the left of the cursor, if there is one. Return terminates the collecting of input characters. The digit characters are converted to a 16 bit word value and sent to a register table (%R) location in the PLC CPU.

Both TASK1 and TASK 2 use PCM serial port 2 to communicate with the OIT. When one of the tasks is waiting for data from the user, the other task may receive an AST and try to display its own message. The second task must be prevented from displaying a message until the first task has received all its input data.

This function demonstrates the preferred technique for controlling access to VTOS services. A named semaphore controls access to a locking flag, and the flag controls access to the port.

Caution

An application task should never call a VTOS service function while the task has control of a named semaphore. Deadlocks between tasks may result.

Semaphore deadlocks occur in this way. Suppose task A controls semaphore X and task B controls semaphore Y at the same time. Now suppose that task A is executing and needs to acquire semaphore Y before it can release semaphore X. When task A calls **Block_sem** to acquire semaphore Y, VTOS will prevent task A from executing again until task B releases it.

Suppose further that task B needs to acquire semaphore X before it can release semaphore Y. When task B calls **Block_sem**, it will also be prevented from executing. The process is deadlocked because each task is prevented from releasing the semaphore that the other task needs. Deadlocks involving more than two semaphores and more than two tasks are also possible.

Caution

VTOS uses semaphores internally to control access to PCM resources. Consequently, calling a VTOS service function or standard C library I/O function (such as printf) from an application task that has control of a semaphore can easily cause a semaphore deadlock.

The **other_task_ast** function blocks on the **tmp_buf_sem** semaphore. When the semaphore is available, **other_task_ast** tests **port_alloc_flag** in the shared memory module. If the flag contains a non-zero value, indicating that the serial port is in use, **other_task_ast** unblocks the semaphore and waits 50 milliseconds. Then **other_task_ast** blocks on the semaphore and tests the flag again. This process is repeated until the flag indicates the port is available.

When the port becomes available, **other_task_ast** allocates it for the current task and then unblocks the semaphore. At this point, **other_task_ast** is ready to send a message to the OIT and wait for input, as described above. When the OIT transaction is complete, **other_task_ast** blocks on the semaphore until the flag is available. Once the semaphore is acquired, the port is released by setting the flag to zero, and the semaphore is unblocked.

DATA

The DATA task has only one function, **main**. When VTOS starts **main**, it waits for four seconds to give the other PCM tasks time to complete their initialization. If DEBUG is defined, **main** opens the debug file and announces its task name and number. Then it opens the database file and checks its size. If the database file is smaller than the size specified by the product of RECORD_SIZE and MAX_RECORDS, **main** extends it to the correct size.

Next, **main** opens separate channels on the CPU: device for receiving COMMREQ messages from the PLC CPU and for responding to them.

With all the preliminaries completed, **main** enters a non-terminating **for** loop. At the top of the loop, a WAIT mode **Read_dev** call causes DATA to stop executing until a COMMREQ arrives, an error occurs, or the **Read_dev** call is aborted by some other task. If the data returned by **Read_dev** is smaller than the size of a COMMREQ message, the **continue** statement jumps to the top of the loop, skipping the code where the data is processed.

The COMMREQ message specifies a PLC memory location where the PLC CPU expects to receive a COMMREQ status value. The PLC memory type and offset of the status address are extracted from the COMMREQ and assigned to the corresponding members of the **st_addr** structure. A **Special_dev** call using *special_code* 8 sets the PLC CPU address of the **stat_hndl** channel to the new memory type and offset. Finally, a WAIT mode **Write_dev** call sends the value 1 to the status address.

Note that the code expects all the COMMREQ data to be in the message. Supporting COMMREQs with external data buffers will require a change to the **msg_buf** union member where **main** looks for the COMMREQ status location plus additional code to process a COMMREQ data buffer.

Next, command data is extracted from the COMMREQ message and assigned to the **command**, **recnum**, and **cpuloc** variables. The **cpuloc** value is used to construct a VTOS device name string for CPU register (%R) memory in **tmp_str**. The **recnum** value is checked; DATA exits if it is invalid.

DATA responds to just two **command** values:

1. Read CPU data and store it as records containing RECORD_WORDS words, in a database file in the PCM RAM disk, and
2. Copy data records from the database file to the CPU.

When **command** specifies copying data from the CPU to the database file (value 1), DATA opens a CPU channel, reads the data, and writes it to the database record specified by **recnum**. If an error occurs while attempting to read the CPU data, the command is ignored.

When the COMMREQ specifies copying data from the file to the CPU (value = 2), the specified database record is read, and the data is written the the CPU.

If the COMMREQ contained an unknown command, DATA exits.

PLC Ladder Program

The Logicmaster 90-70 version of the ladder program, from folder \PCMC\EXAMPLES\DEMO_3T\PLC_70, is shown here as Listing 9.1. The Logicmaster 90-30 version, which is not shown, requires a few more rungs because Series 90-30 COMMREQ function blocks do not pass power flow.

In Listing 9.1, rung 6 initializes the PCM COMMREQ status locations and clears the internal contacts which latch COMMREQ faults. Note that the status locations must contain non-zero values before the first COMMREQs can be sent.

Rung 7 is a timer which delays the first COMMREQs until five seconds after the first scan. It is reset on the first scan.

Rung 9 initializes the command and data blocks for COMMREQs sent to the DATA task. The BLKMV function blocks are activated on every sweep; new data values are used immediately in COMMREQs.

Rungs 11 and 12 latch a COMMREQ request in %M0003 when %M0001 is turned on. The on-transition coil, %M0002, assures that %M0001 must be turned off and then on again before another COMMREQ will be requested.

Rung 14 sends COMMREQs to the DATA task. First, a COMMREQ request must be latched in %M0003; the COMMREQ fault latch, %M0006, must be off; and the delay timer in rung 7 must have expired, closing %T0001. If all these conditions are met, the COMMREQ status value in %R00019 is checked. If the status value is non-zero, the status location is cleared to zero and the COMMREQ is sent. Power flow through the COMMREQ function block resets the request latch. If a COMMREQ fault occurs, the fault latch, %M0006, prevents more COMMREQs until the program is stopped and restarted.

In the Series 90-30 version of the program, three ladder rungs perform the work of rung 14 in this version.

Ladder rungs 16 through 21 send COMMREQs to PCM TASK2. Except for data references, they are identical to rungs 9 through 14.

```
12-10-92  15:22    GE FANUC SERIES 90-70 DOCUMENTATION (v3.04)      Page    1
                   PCM C Demo Application For Series 90-70 PLC

|[  START OF LD  PROGRAM PLC_70   ]      (*                                *)
|
|[     VARIABLE DECLARATIONS      ]
|
|[   PROGRAM BLOCK DECLARATIONS   ]
|
|[           INTERRUPTS           ]
|
|[     START OF PROGRAM LOGIC     ]
|
| << RUNG 5 >>
|
|INI_FSC
|(*  COMMENT  *)
|
| (*************************************************************************)
| (* On the first scan, initialize the PCM COMMREQ status locations to     *)
| (* non-zero values to permit sending the first COMMREQs.  Clear the      *)
| (* COMMREQ fault latches.  Reset the COMMREQ delay timer and start the   *)
| (* 5 second delay for the first COMMREQ.                                 *)
| (*************************************************************************)
|
| << RUNG 6 >>
|
|FST_SCN +-----+                +-----+                              %M00006
+--] [---+MOVE_+----------------+MOVE_+--------+----------------------(RM)-
|        | INT |                | INT |        |
|        |     |                |     |        |                      %M00026
| CONST -+IN  Q+-%R00019  CONST -+IN  Q+-%R00029+----------------------(RM)-
| +00001 | LEN |          +00001 | LEN |
|        |00001|                |00001|
|        +-----+                +-----+
|
| << RUNG 7 >>
|
|%T00001 +-----+                                                       %T00001
+--]/[---+ONDTR+-------------------------------------------------------------(S)--
|        |0.10s|
|FST_SCN |     |
+--] [---+R    |
|        |     |
| CONST -+PV CV+-
| +00050 |     |
|        +-----+
|        %R00015
|
| << RUNG 8 >>
|
|INI_CRD
|(*  COMMENT  *)
|
Program: PLC_70          C:\PCMC\EXAMPLES\DEMO_3T\PLC_70         Block: _MAIN
```

Listing 9.1

```
12-10-92  15:22   GE FANUC SERIES 90-70 DOCUMENTATION (v3.04)       Page    2
                  PCM C Demo Application For Series 90-70 PLC

| (*************************************************************************)
| (* Initialize the command and data blocks for COMMREQs sent to the DATA  *)
| (* task.  The status location is type 8, offset 18 (%R0019).             *)
| (*************************************************************************)
|
| << RUNG 9 >>
|
|ALW_ON  +-----+                 +-----+
+--] [---+BLKMV+-----------------+BLKMV+-
|        | INT |                 | INT |
|        |     |                 |     |
| CONST -+IN1 Q+-%R00001  CONST -+IN1 Q+-%R00008
| +00003 |     |           +00003 |     |
|        |     |                  |     |
| CONST -+IN2  |           CONST -+IN2  |
| +00000 |     |           +00100 |     |
|        |     |                  |     |
| CONST -+IN3  |           CONST -+IN3  |
| +00008 |     |           +00000 |     |
|        |     |                  |     |
| CONST -+IN4  |           CONST -+IN4  |
| +00018 |     |           +00000 |     |
|        |     |                  |     |
| CONST -+IN5  |           CONST -+IN5  |
| +00000 |     |           +00000 |     |
|        |     |                  |     |
| CONST -+IN6  |           CONST -+IN6  |
| +00000 |     |           +00000 |     |
|        |     |                  |     |
| CONST -+IN7  |           CONST -+IN7  |
| +00001 +-----+           +00000 +-----+
|
| << RUNG 10 >>
|
|ATV_CRD
|(*  COMMENT  *)
|
| (*************************************************************************)
| (* This discrete logic detects an activation contact for sending COMMREQ *)
| (* to the DATA task and remembers it until the next COMMREQ is sent.     *)
| (* Toggling %M0001 sets %M0003, which remains set until the COMMREQ is   *)
| (* sent.  The on-transition coil, %M0002, assures that %M0003 is set only*)
| (* on the sweep when %M0001 is toggled on.                               *)
| (*************************************************************************)
|
| << RUNG 11 >>
|
|%M00001                                                          %M00002
+--] [-----------------------------------------------------------------(^)--
|
| << RUNG 12 >>
|
|%M00002                                                          %M00003
+--] [-----------------------------------------------------------------(SM)-

Program: PLC_70          C:\PCMC\EXAMPLES\DEMO_3T\PLC_70         Block: _MAIN
```

Listing 9.1, Continued.

```
12-10-92  15:22   GE FANUC SERIES 90-70 DOCUMENTATION (v3.04)       Page    3
                  PCM C Demo Application For Series 90-70 PLC

| << RUNG 13 >>
|
|SND_CRD
|(*  COMMENT  *)
|
|*************************************************************************)
| (* If a COMMREQ has been requested, and previous COMMREQs have not caused*)
| (* a fault, and at least 5 seconds have elapsed since the first scan,    *)
| (* then check the status location for the COMMREQ.  If this is the first *)
| (* COMMREQ, or the PCM has acknowledged the previous one, then clear the *)
| (* status location, send a new COMMREQ to the DATA task, and reset the   *)
| (* request latch.  If a COMMREQ fault occurs, set the fault latch.       *)
| (*************************************************************************)
|
| << RUNG 14 >>
|
|%M00003 %M00006 %T00001 +-----+
+--] [-----]/[-----] [---+ NE_ +-
|                        | INT |
|                        |     |         +-----+              +-----+  M00003
|                %R00019-+I1  Q+---------+MOVE_+--------------+COMM_+---(RM)-
|                        |     |         | INT |              | REQ |
|                        |     |         |     |              |     | %M00006
|                 CONST -+I2   |  CONST -+IN  Q+-%R00019 %R00001-+IN+---(SM)-
|                  +00000+-----+  +00000 | LEN |              |     |
|                                        |00001|              |     |
|                                        +-----+       CONST -+SYSID|
|                                                        0002 |     |
|                                                             |     |
|                                                    CONST -+TASK |
|                                                  00000019 +-----+
|
| << RUNG 15 >>
|
|INI_CR2
|(*  COMMENT  *)
|
| (*************************************************************************)
| (* Initialize the command and data blocks for COMMREQs sent to TASK2.    *)
| (* The status location is type 8, offset 28 (%M0029).                    *)
| (*************************************************************************)
|

Program: PLC_70          C:\PCMC\EXAMPLES\DEMO_3T\PLC_70         Block: _MAIN
```

Listing 9.1, Continued.

```
12-10-92  15:22   GE FANUC SERIES 90-70 DOCUMENTATION (v3.04)       Page    4
                  PCM C Demo Application For Series 90-70 PLC

| << RUNG 16 >>
|
|ALW_ON  +-----+
+--] [---+BLKMV+-
|        | INT |
|        |     |
| CONST -+IN1 Q+-%R00020
| +00001 |     |
|        |     |
| CONST -+IN2  |
| +00000 |     |
|        |     |
| CONST -+IN3  |
| +00008 |     |
|        |     |
| CONST -+IN4  |
| +00028 |     |
|        |     |
| CONST -+IN5  |
| +00000 |     |
|        |     |
| CONST -+IN6  |
| +00000 |     |
|        |     |
| CONST -+IN7  |
| +01234 +-----+
|
| << RUNG 17 >>
|
|ATV_CR2
|(*  COMMENT  *)
|
| (*************************************************************************)
| (* Latch a request to send a COMMREQ to TASK2 when %M0021 is toggled on. *)
| (* See the comment at RUNG 10 for details.                               *)
| (*************************************************************************)
|
| << RUNG 18 >>
|
|%M00021                                                          %M00022
+--] [-----------------------------------------------------------------(^)-
|
| << RUNG 19 >>
|
|%M00022                                                          %M00023
+--] [-----------------------------------------------------------------(SM)-
|
| << RUNG 20 >>
|
|SND_CR2
|(*  COMMENT  *)
|


Program: PLC_70          C:\PCMC\EXAMPLES\DEMO_3T\PLC_70         Block: _MAIN
```

Listing 9.1, Continued.

```
12-10-92  15:22   GE FANUC SERIES 90-70 DOCUMENTATION (v3.04)        Page    5
                  PCM C Demo Application For Series 90-70 PLC

| (*************************************************************************)
| (* If a COMMREQ has been requested, and there are no faults from previous *)
| (* COMMREQs, and at least 5 seconds have elapsed since the first scan,    *)
| (* then check the COMMREQ status location before sending a new COMMREQ to *)
| (* TASK2.  See the comment at RUNG 13 for details.                       *)
| (*************************************************************************)
|
| << RUNG 21 >>
|
|%M00023 %M00026 %T00001+-----+
+--] [-----]/[-----]/[--+ NE_ +-
|                       | INT |
|                       |     |         +-----+                 +-----+%M00023
|                %R00029-+I1  Q+---------+MOVE_+-----------------+COMM_+--(RM)-
|                       |     |         | INT |                 | REQ |
|                       |     |         |     |                 |     |%M00026
|                 CONST -+I2   |  CONST -+IN  Q+-%R00029 %R00020-+IN FT+--[SM)-
|                  +00000+-----+  +00000 | LEN |                 |     |
|                                        |00001|                 |     |
|                                        +-----+          CONST -+SYSID|
|                                                           0002 |     |
|                                                                |     |
|                                                       CONST -+TASK |
|                                                     00000018 +-----+
|
|[      END OF PROGRAM LOGIC      ]
|

Program: PLC_70          C:\PCMC\EXAMPLES\DEMO_3T\PLC_70         Block: _MAIN-
```

Listing 9.1, Concluded.

Chapter 10 Applications in ROM

Two PCM models, the Series 90-70 PCM 711 and Series 90-30 PCM 300, use a pair of read-only memory (ROM) devices. One ROM contains the VTOS operating system and other system firmware; the PCM will not operate without it. However, the second ROM contains firmware for the MegaBasic programming environment and the CCM communication protocol. This second ROM may be replaced by one containing a custom application. ROM-resident applications provide several advantages:

1. The code and initial data values are completely non-volatile. Code stored in PCM battery-backed RAM depends on a battery for retention while the PLC is powered off. However, ROM-resident applications require a battery only when data they modify at run time must be preserved while power is off. In addition, ROM-resident code can never be corrupted by program errors, although RAM-resident code can.
2. Storing the application in ROM frees all of RAM for program data. Some applications may fit in a smaller, less expensive memory option.

Restrictions

Table 10-1 below shows the memory models which support code in ROM and the code, data, and stack size limits for each.

Table 10-1. Memory Models Which Support Code in ROM

Memory Model	Max ROM Code	Max Static Data	Max Stack Data
Small	64 Kbytes	64 Kbytes	64 Kbytes
Medium	128 Kbytes *	64 Kbytes	64 Kbytes
Large	Not Supported	Not Supported	Not Supported

* Code size is limited only by available ROM.

In addition, the MegaBasic programming environment and CCM communication protocol are not available in a PCM with a custom application in ROM.

Building ROM Applications

These steps are required to develop ROM-based PCM applications:

1. One or more application tasks must be designed, coded, tested and debugged. During this phase, the application code is loaded to PCM RAM and executed there. See chapter 3, *Creating and Running PCM C Programs*, for a description of this process.

2. When development is complete, the BLD_PROM utility is used to package all the application tasks plus a PCMEXEC.BAT file to run them when the host PCM powers up or is reset. BLD_PROM produces a ROM image file, which contains all the data to be programmed in the ROM. Chapter 11, *Utilities*, describes the BLD_PROM utility and the process of creating a ROM image.

3. The ROM image file is used to program an erasable, programmable read-only memory (EPROM) part. The table below shows EPROM device part numbers and locations for the PCM 711 and PCM 300 models.

Table 10-2. ROM Device Part Numbers and Locations

PCM Model	EPROM Part Number *	EPROM Location
PCM 711	27C1024-155	U59
PCM 300	27C010-205	U35

* Higher speed parts may be substituted.

4. The standard PCM EPROM in the location specified above is removed and replaced by the EPROM containing your ROM-based application.

Note

EPROM programming hardware is not available from GE Fanuc Automation. However, a number of suitable models are offered by several manufacturers.

Chapter 11 Utitlies

This chapter describes the utility programs provided with the PCM C toolkit.

STKMOD Program

STKMOD.EXE is a utility program used to assign a stack size to PCM executable (.EXE) files. Its command line format is:

```
> stkmod [options] <Enter>
```

where options includes one or more of

```
?
/h
–h
/s <stack size in bytes>
–s <stack size in bytes>
<exe file name>
```

The **<stack size in bytes>** is a decimal number specifying the new stack size value; and **<exe file name>** is the name of the PCM.EXE file to be modified, with or without the EXE file extension and dot ('.') character. Options may appear in any order, and the case of alphabetic characters in the options is ignored.

Invoking STKMOD.EXE with no options or with any of the **?**, **/h**, or **–h** options causes STKMOD to print its help text:

```
> stkmod

      GE Fanuc Automation PCM EXE File Stack Size Utility, Version 1.00
         Copyright (c) 1992, GE Fanuc Automation North America, Inc.
                              All rights reserved.

usage:    stkmod –h
          stkmod exefile  [/s <stack bytes>]
      where <stack bytes> is a decimal number in 1024 .. 65520

example:  stkmod myapp /s 2048
```

Invoking STKMOD.EXE with just the **<exe file name>** option displays the current stack size value without changing it:

```
> stkmod hello

      GE Fanuc Automation PCM EXE File Stack Size Utility, Version 1.00
         Copyright (C) 1992, GE Fanuc Automation North America, Inc.
                              All rights reserved.

HELLO.EXE                          (hex)     (dec)

old stack size in paragraphs       0800       128
old stack size in bytes            0800      2048
```

When the **/s** or **-s** option is used, the stack size specification in the file specified by **<exe file name>** is modified. If **<stack size in bytes>** is not a decimal number, or is less than 1024, the stack size will be set to 1024 bytes. If **<stack size in bytes>** is greater than 65,520 bytes, the stack size will be set to 65,520 bytes. If the specified stack size is at least 1024, less than 65,520, and an integer multiple of 16 bytes, the specified value will be used. Otherwise, the specified value will be adjusted to the next larger multiple of 16 bytes. When STKMOD modifies the specified value, it displays this message:

```
stack size adjusted to xxxxx bytes
```

For example, entering either of these command lines:

```
stkmod hello /s abcd
stkmod hello /s 1023
```

results in a new stack size of 1024 bytes. Entering these command lines:

```
stkmod hello /s 100000
stkmod hello /s 1025
stkmod hello /s 1040
```

results in new stack sizes of 65520 bytes, 1040 bytes, and 1040 bytes, respectively.

STKMOD produces these error messages:

Table 11-1. STKMOD Error Messages

Message	Description
Invalid option:	One of the command line options was invalid.
No stack size value specified	The **/s** option was used, but was not followed by a value. The space between the option and the value may have been omitted.
can't open file:	The specified EXE file could not be opened.
premature end of data reading file:	The specified EXE file is corrupted.
invalid EXE file:	The specified EXE file does not begin with the MS-DOS executable file marker.
error writing file:	The modified EXE file header could not be written to disk. The file may have read-only access.

PCMDUMP Program

PCMDUMP.EXE is a utility program for formatting the binary output of the PCM task dump (PD) command.

To use PCMDUMP.EXE:

1. Stop the application in the task state you want to examine by pressing the restart / reset button for less than 5 seconds (a soft reset). If your application has serious problems, the PCM may reset itself.
2. If your PCM is configured to start the application whenever a soft reset occurs, a hard reset (pressing the restart / reset button for ten seconds) will be necessary to access the PCM command interpreter. The hard reset has no effect on the saved dump information.
3. Start TERMF with the PC serial port connected to the PCM port 1. Use the "**!!**" command to put the PCM in interactive command mode. At the PCM prompt ('>'), use the PD command to get a binary PCMDUMP.OUT file in the current directory of your PC.
4. Exit from TERMF. From the MS-DOS prompt, run the PCMDUMP utility:

```
> PCMDUMP
```

or

```
> PCMDUMP >DUMP.ASC
```

or

```
> PCMDUMP >LPT1
```

By default, PCMDUMP.EXE sends its output to the PC display. Redirecting the output to a file, such as DUMP.ASC (as shown in the second example), allows you to analyze the dump information using a text editor. You can also redirect output to a printer, as in the third example.

There are two kinds of task state information in the output from PCMDUMP.EXE: task control block data, and task register and stack data. Here is an example, showing the task control blocks for the VTOS real-time clock task (Task ID = 0000) and two user tasks (Task ID = 000E and 000F hexadecimal).

```
      GE Fanuc Automation PCM Task State Dump Utility, Version 1.02
        Copyright (c) 1992, GE Fanuc Automation North America, Inc.
                          All rights reserved.

TASK CONTROL BLOCKS:

Task ID                                  : 0000
Current state                            : 0005 Waiting for local event flag
Old state                                : 0001
Current stack pointer                    : 02FD:02E2
Local event flags which have been set    : 0000
Local event flags where task is waiting  : 0007
Global event flags where task is waiting : 0000
Other tasks which task is waiting for    : 0000
First AST block for task                 : 0000
Last AST block for task                  : 0000
Suspend count                            : 0000
Task's initial data segment              : 0000
Task's initial stack segment             : 02FD
Safe point address                       : 0000
Semaphore count for setting safe point   : 0000
Semaphore count for I/O operations       : 0000
Segment of STDIN Device Access Block     : 0538
Segment of STDOUT Device Access Block    : 053A
Segment of STDERR Device Access Block    : 053A
Task environment block address           : FD8E:0B00
Link field for tasks waiting at semaphore: FFFF
Semaphore address if waiting at semaphore: 0000
Flag for enabling ASTs                   : 0001
VME window selector code                 : 00
VME address modifier code                : 29

     .         .         .         .         .         .         .
     .         .         .         .         .         .         .

Task ID                                  : 000D
Current state                            : 0000  Task was never allocated

Task ID                                  : 000E
Current state                            : 0001  Task is executing
Old state                                : 0000
Current stack pointer                    : 06FD:03BA
Local event flags which have been set    : 0000
Local event flags where task is waiting  : 0000
Global event flags where task is waiting : 0000
Other tasks which task is waiting for    : 0000
First AST block for task                 : 0000
Last AST block for task                  : 0000
Suspend count                            : 0000
Task's initial data segment              : 073E
Task's initial stack segment             : 06FD
Safe point address                       : 0000
Semaphore count for setting safe point   : 0000
Semaphore count for I/O operations       : 0000
Segment of STDIN Device Access Block     : 045E
Segment of STDOUT Device Access Block    : 0611
Segment of STDERR Device Access Block    : 0611
Task environment block address           : 06F7:0000
Link field for tasks waiting at semaphore: 0000
Semaphore address if waiting at semaphore: 0000
Flag for enabling ASTs                   : 0001
VME window selector code                 : 00
VME address modifier code                : 29
```

```
Task ID                                    : 000F
Current state                              : 0003  Waiting for an asynch trap
Old state                                  : 0001
Current stack pointer                      : 0687:03B8
Local event flags which have been set      : 0000
Local event flags where task is waiting    : 0000
Global event flags where task is waiting   : 0000
Other tasks which task is waiting for      : 0000
First AST block for task                   : 0000
Last AST block for task                    : 0000
Suspend Count                              : 0000
Task's initial data segment                : 06C8
Task's initial stack segment               : 0687
Safe point address                         : 0000
Semaphore count for setting safe point     : 0000
Semaphore count for I/O operations         : 0000
Segment of STDIN Device Access Block       : 045E
Segment of STDOUT Device Access Block      : 0611
Segment of STDERR Device Access Block      : 0611
Task environment block address             : 0613:0000
Link field for tasks waiting at semaphore  : 0000
Semaphore address if waiting at semaphore  : 0000
Flag for enabling ASTs                     : 0001
VME window selector code                   : 00
VME address modifier code                  : 29
```

The task control block fields are described in the following sections:

Task ID: This field contains a task number in the range 0000 through 000F hexadecimal (0 through 15 decimal) inclusive. If the task number has not been used since the last PCM reset, the binary PCMDUMP.OUT file actually contains zero in this field. However, PCMDUMP.EXE prints an ID value for every task, regardless of the value in the binary dump.

Current State: This field contains one of the values from the following table.

Table 11-2. Current State Values

Current State Value	PCMDUMP State Name	Description
0	Task was never allocated.	This task ID has never been assigned to a task since the most recent PCM reset. Note that task number zero should **never** be in this state.
	Task was terminated.	This task ID was assigned to a task after the most recent PCM reset, but the task has terminated.
1	Task is executing.	If this task has the lowest ID value of all the tasks which have the current state value one and is not suspended, it was executing when the reset occurred. The code which was executing was mainline code (that is, called directly or indirectly from the task's `main` function) rather than an AST function.
	Task is ready.	If this task is not suspended, and another task has a smaller Task ID value and also has the current state value one (1), this task was ready to execute when the reset occurred, but its priority was not high enough to gain control of the PCM processor.
	Task is suspended.	If the Suspend count value for this task is non-zero, the task was suspended when the reset occurred.
2	Executing an asynch trap.	This task was executing an AST function when the reset occurred.
3	Waiting for an asynch trap.	This task had called `Wait_ast` and was still waiting.
4	Waiting for I/O completion.	This task was waiting for a WAIT mode I/O operation to complete when the reset occurred.
5	Waiting for local event flag.	This task was waiting for a local event flag to be set by another task when the reset occurred.
6	Waiting for global event flag.	The task was waiting for a global event flag to be set by another task when the reset occurred.
7	Waiting for a timer.	This task had called `Wait_time` and was still waiting.
8	Waiting for another task.	This task had called `Wait_task` and was still waiting.
9	Waiting at a semaphore.	This task blocked on a semaphore by calling `Link_sem` or `Block_sem` and was still waiting.

Old State: When a task is waiting for some event, this field contains the task's state before it began waiting.

Current Stack Pointer: This field contains the far address of the top of the task's stack.

Local Event Flags Which Have Been Set: This field contains the current state of the task's local event flags.

Local Event Flags Where Task is Waiting: This field contains a local event flag mask in which all the local event flags where the task is waiting, if any, are set. If this task is not waiting for local event flags, this field is zero.

Global Event Flags Where Task is Waiting: This field contains a global event flag mask in which all the global event flags where the task is waiting, if any, are set. If this task is not waiting for global event flags, this field is zero.

Other Tasks Which Task is Waiting for: This field contains a task mask in which the bit of the task for which this task is waiting, if any, is set. If this task is not waiting for another task, this field is zero.

First AST Block for Task: If this field is non-zero, it contains the segment part of the far address of the first item on the linked list of AST blocks which are ready for this task to process. AST blocks always begin at offset zero in the specified segment. If there are no AST blocks for this task, this field is zero.

Last AST Block for Task: If this field is non-zero, it contains the segment part of the far address of the last item on the linked list of AST blocks which are ready for this task to process. AST blocks always begin at offset zero in the specified segment. If there are no AST blocks for this task, this field is zero.

Suspend Count: This field contains the **`Suspend_task`** count for this task. If the task has not been suspended, this field is zero.

Task's Initial Data Segment: This field contains the data segment (DS register) value assigned to the task when it was started.

Task's Initial Stack Segment: This field contains the stack segment (SS register) value assigned to the task when it was started.

Safe Point Address: When a PCM device driver is executing, this field contains the stack pointer (SP) register value on entry. It is used to locate the stack frame where return values will be placed.

Semaphore Count for Setting Safe Point: This field controls access to the Safe point address field when one PCM device driver calls another.

Semaphore Count for I/O Operations: Unused; reserved.

Segment of STDIN Device Access Block: This field contains the segment part of the far address of a device access block used as the STDIN channel by this task. The offset part of the address is zero.

Segment of STDOUT Device Access Block: This field contains the segment part of the far address of a device access block used as the STDOUT channel by this task. The offset part of the address is zero.

Segment of STDERR Device Access Block: This field contains the segment part of the far address of a device access block used as the STDERR channel by this task. The offset part of the address is zero.

Task environment block address: This field contains the segment part of the address of the environment block for this task. The offset part of the address is zero.

Link field for tasks waiting at semaphore: This field may contain the segment part of the FAR address of another task control block. When two or more tasks wait at the same named semaphore, their task control blocks are placed on a linked list in the order of their priorities.

Semaphore address if waiting at semaphore: If the task is waiting at a named semaphore, this field contains the segment part of the semaphore address; otherwise, this field contains zero. Named semaphores always begin at offset zero in the specified segment.

Flag for enabling ASTs: This field is one when ASTs are enabled for the task; otherwise, ASTs are disabled.

VME window selector code: This field contains the VME block number used for VMEbus access by the task. The value is useful only in a Series 90-70 PCM. See **`Set_vme_ctl`** in the *PCM C Function Library Reference Manual*, GFK-0772, for more information on accessing VMEbus memory.

VME address modifier code: This field contains the VME address modifier (AM) code. This value is also useful only in a Series 90-70 PCM.

Note that the task control block data for tasks which were not active when the reset occurred, such as task 000D hexadecimal, contains only the Task ID and Current state fields.

Task Register and Stack Data

A portion of the stack for the PCM real-time clock (RTC) task and the two application tasks are shown below.

```
REGISTERS and STACK of task 00:

AX=0007  BX=0032  CX=0700  DX=0104  SP=02FC  BP=02FC  SI=0018  DI=0000
DS=0000  ES=0000  SS=02FD  CS=E55E  IP=5F0A   NV UP EI PL ZR NA PE NC

  5A3F  E55E  0002  030C  02FD  0002  0314  02FD
  0B38  FD8E  0B40  FD8E  0B20  FD8E  0000  041A
  0B4E  FD8E  BBBB

    .    .    .    .    .    .    .    .    .    .    .    .    .    .

REGISTERS (assuming a pushbutton reset) and STACK of task 0E:

AX=000E  BX=0000  CX=03DC  DX=073E  SP=03D4  BP=03E2  SI=0BB4  DI=468B
DS=073E  ES=0000  SS=06FD  CS=0620  IP=01AE   NV UP EI NG NZ AC PE CY

  0109  0001  03F4  06FD  0001  03F8  06FD  03E4
  5A3F  E55E  0001  03F4  06FD  0001  03F8  06FD
  0038  06F7  0020  06F7  0000  061D  BBBB  076C
  0618  076C  06FC  002E  FF0E  1111  B5E1  DF5E
  0000  0000  0000  0000  0000  0000  0000  0000
  0000  0000  0000  0000  0000

REGISTERS and STACK of task 0F:

AX=000F  BX=0000  CX=03DC  DX=06C8  SP=03D2  BP=03E2  SI=FF6E  DI=9EC4
DS=06C8  ES=0000  SS=0687  CS=0620  IP=030E   NV UP EI PL ZR NA PE NC

  01AD  0109  0001  03F4  0687  0001  03F8  0687
  03E4  5A3F  E55E  0001  03F4  0687  0001  03F8
  0687  0038  0613
```

The register and stack data is displayed in two parts: the contents of PCM microprocessor registers and the first few words of data on the task's stack. No register or stack data is displayed the for tasks which were not active when the reset occurred, such as task 000D hexadecimal.

The contents of thirteen microprocessor registers (AX, BX, etc.) are displayed as hexadecimal values. The processor status word, or flags register, is displayed as eight individual flags:

Table 11-3. Flags Register

Flag Name	Symbol and Meaning When Not Set	Symbol and Meaning When Set
Overflow flag	NV No overflow.	OV Overflow occurred.
Direction flag	UP Up.	DN Down.
Interrupt flag	DI Disable interrupts.	EI Enable interrupts.
Sign flag	PL Plus.	NG Negative.
Zero flag	NZ Not zero.	ZR Zero.
AL Carry / Borow flag	NA No AL register carry or borrow.	AC AL carry or borrow occurred.
Parity flag	PO Parity odd.	PE Parity even.
Carry / Borow flag	NC No carry or borrow.	CY Carry or borrow occurred.

For more information on status flags and the processor status word, refer to Intel Corporation documentation on the 80186 and 80188 microprocessors.

The register and stack data display for the task which was interrupted when the reset occurred (task 0E hexadecimal, in this case) is different in two respects. First, the header for the stack data contains the disclaimer, ''assuming a pushbutton reset''. Register values are saved in slightly different order, depending on whether the reset was caused by the reset / restart pushbutton, by a COMMREQ message, or by a severe software error which caused the PCM to reset itself. Unfortunately, DCMDUMP does not know which kind of reset actually occurred. It can only assume that the button was pushed. When some other event caused the reset, the register values will not be correct.

Only the executing task is affected by this difficulty. Register values for the other tasks are always saved in the same order by VTOS.

The second difference is the number of stack words which are displayed. The executing task stack display contains 45 words, while only 19 are displayed for the other tasks.

Note that the stack pointer (SP) register value is different from the one displayed in the task control block (TCB) for the task. The Current stack pointer field of the TCB points to the start of the saved registers. In the register display, the SP register value is adjusted to point to the start of the stack word display.

Note also that the stack word display may include values which are actually beyond the end of the task's stack. The stack for task 0E hexadecimal was set to 1024 bytes (0400 hexadecimal) by the STKMOD utility. The offset value of the last stack word is 03FE hexadecimal.

The SP register value tells us that the stack word display for task 0E begins at offset 03D4 hexadecimal in the stack segment. The leftmost value in the first row of the stack display is the word at that stack location. Since each row of the display contains 8 words (16 decimal or 10 hexadecimal bytes), it follows that the offset of the word at the start of the second row is 03E4 hexadecimal. Similarly, the third row starts at offset 03F4 hexadecimal. Counting along the third row by twos, we find that the value at offset 03FE is 061D hexadecimal. The next value, BBBB hexadecimal, is the start of a different PCM memory block. BBBB is actually the value which VTOS uses to mark the start of free memory blocks. The last 23 words of the stack display are beyond the end of the stack segment for task 0E. This version of PCMDUMP has no knowledge of task stack sizes.

Using Microsoft Map Files

For small model tasks, all executable code is contained in a single code segment. In map files produced by the Microsoft linker (for example, HELLO.MAP), the code segment value is shown as zero (0000 hexadecimal). In the **`Publics by Value`** section of the map file, the offset value within the code segment for each function is also shown. To identify the function which each task was executing most recently before the reset occurred, compare the IP register value from the task's stack dump to the offsets in **`Publics by Value`**. The function which was executing or interrupted will have the largest offset value which is smaller than IP.

If the PCM application uses more than one PCM task, the Task ID value for each .EXE file is determined by the R (Run) commands in PCMEXEC.BAT which are used to start them. See the R (Run) command in appendix B of this manual for details.

The situation is more complex for medium and large model tasks because there is more than one code segment. The code segment (CS) register value from a PCM stack dump must be used to identify the code segment which was executing when the reset occurred.

The PCM directory command, D, provides an entry point address for all executable PCM modules. This address is the PCM memory location of the public symbol **`__astart`** in the MAP file. The segment value of the entry point address is used to calculate the code segment value in the MAP from the corresponding CS register value in a PCM stack dump. For any code segment,

Map code segment value = CS – entry point segment value + **`__astart`** segment value from MAP file

For example, the stack dump of task E hexadecimal in the previous section shows that it was executing in code segment **`0A4F`** hexadecimal when the reset occurred. If the PCM directory command shows **`0837:00A0`** as the entry point address for this task, and the MAP file gives **`0000:00A0`** for the location of **`__astart`**, then the MAP value of the code segment which was executing when the reset occurred is:

```
0A4F – 0837 + 0000 = 0218
```

Within the segment, individual functions can be identified by the stack dump IP register value in the same way as for small model tasks.

BLD_PROM Program

BLD_PROM.EXE is the utility program used to build the binary image files for programming erasable, programmable, read-only memory (EPROM) devices. The actual programming of EPROM devices requires an EPROM programmer; EPROM programmers are not available from GE Fanuc Automation. For more information on PCM applications in ROM, see chapter 10 of this manual.

To invoke BLD_PROM, simply type: **BLD_PROM** at the MS-DOS prompt. BLD_PROM will ask you for the inputs it needs. Most prompt messages from BLD_PROM contain a default value, which is displayed in square brackets ('[]'). Most defaults can be selected simply by pressing the **<Enter>** key. However, if BLD_PROM is expecting a string as input (for example, a file name), you must select the default by entering a semicolon (';') character followed by the **<Enter>** key.

In this example BLD_PROM session, user input is shown in *this typeface*.

```
>BLD_PROM

Bld_prom utility
Copyright 1989 GE Fanuc Automation North America, Inc.

Please enter initialization file name  ?  ;<Enter>

Please enter PROM address (1 = c0000. 2 = a0000)  [1]  ?  <Enter>

Please enter copyright text file name [copr.txt]  ?  \PCM\EXAMPLES\COPR.TXT
<Enter>

Please enter file name to be loaded into the PROM image  ?  \PCM\EXAMPLES\RUN
HELLO.BAT<Enter>

Please enter the name for the module [RUNHELLO.BAT]  ?  PCMEXEC.BAT<Enter>

Do you wish this module to appear in the directory listing  [Y]  ?  <Enter>

Do you wish this module to be copied to RAM before use  [N]  ?  <Enter>

Please enter file name to be loaded into the PROM image  ?  HELLO.EXE<Enter>

Please enter the name for the module  [HELLO.EXE]  ?  ;<Enter>

Do you wish this module to appear in the directory listing  [Y]  ?  <Enter>

stack size  800

Please enter file name to be loaded into the PROM image  ?  ;<Enter>

next available paragraph is c43f:0


>
```

After printing its invocation message, BLD_PROM asks for the name of an initialization file. However, initialization files are not supported by Microsoft LINK; the response is just a semicolon followed by Enter.

BLD_PROM needs to know the starting address for the ROM, because one starting address (C000:0 hexadecimal) is used for the PCM711, PCM301, and PCM311, and a different starting address is used for the PCM300 (A000:0 hexadecimal). Since the target PCM model is the PCM711, the default is correct; this time, the response is just the Enter key.

Next, BLD_PROM prompts for a text file containing a copyright string. An example copyright string file, **\PCMC\EXAMPLES\COPR.TXT**, was copied to your PC hard disk when this software was installed; its full path specification plus the Enter key is the response. The section "Customizing the PROM Copyright String" below explains how to provide a unique copyright for your application.

The first application file for the PROM is a PCM batch file which will run the application whenever the PCM is reset or powered on. This file was also copied to your PC hard disk when this software was installed. Its full path specification, **\PCMC\EXAMPLES\RUNHELLO.BAT**, plus the Enter key is the response.

BLD_PROM asks what file name should be used for RUNHELLO.BAT in the PROM. Rather than the default, name it PCMEXEC.BAT; this is the batch file name which is run automatically on reset or power-up. Use the Enter key to terminate the name.

BLD_PROM also asks whether the file should be visible in the PROM directory listing. You can make it a hidden file by responding with just the 'N' key. Type the Enter key to select the default, which makes it visible.

Since this is a data file, the next prompt asks whether the file should be copied to RAM before use. This file will never need to be changed, so type the Enter key to select the default. You can also use ROM data modules to provide initialization values for read / write modules in RAM. In this case, the module would be copied to RAM before use.

Next, BLD_PROM asks for another file to be put into the PROM. Respond with our example executable file from chapter 3, HELLO.EXE. It is assumed to be in the current PC directory.

Since PCMEXEC.BAT will try to run HELLO.EXE, it should be given the default name, HELLO.EXE, in the PROM. This time a semicolon, as well as Enter, is required.

Make HELLO.EXE visible by answering Enter to the next prompt. EXE files should always be made visible. The PCM directory command, D R, will provide the entry point address in the PROM for debugging purposes, but only if the file is visible.

BLD_PROM informs us that the stack size for HELLO.EXE is 800 hexadecimal (2048 decimal) bytes.

HELLO.EXE is the last file to be loaded into ROM, so the next prompt for a module name is answered with a semicolon and Enter. BLD_PROM tells us that the empty space in ROM begins at address C43F:0 hexadecimal, and then exits. It has created a binary PROM image file named ROM.001 which contains exactly 128K bytes (131072 decimal).

Customizing the PROM Copyright String

Each PCM PROM begins with a copyright message string. The copyright message actually has three purposes:

1. It is a notice of intellectual property rights in the PROM firmware.
2. It provides a trigger for enabling checksum verification of the PROM contents when the PCM is powered on.
3. It also triggers verification at power-up that the firmware has been installed in the correct hardware.

The file \PCMC\EXAMPLES\COPYRTXT contains a sample copyright string which performs all three of these functions:

```
Copr. 1992 GE Fanuc Automation N.A. Inc.^PCM711
```

The six initial characters, "**Copr.** ", are required to enable automatic checksum verification of the PROM when the PCM is reset. We recommend that every PROM image begin with these exact characters, including the dot ('.') and space characters.

The characters "**^PCM711**" enable the optional check that the PROM image was intended for the PCM711 hardware. The location of these characters is unimportant. This table shows the three valid hardware check strings:

Table 11-4. Valid Hardware Check Strings

Hardware Check String	PCM Module Type(s)
^PCM711	PCM711 with any (or no) memory expansion board.
^PCM300	PCM300 module only.
^PCM301	PCM301 and PCM311 module.

Note that the PCM301 and PCM311 do not require separate PROMs.

The copyright information in the string can use any ASCII printing and non-printing characters except NUL (ASCII code zero) and may have any length. BLD_PROM.EXE reads the entire file, appends an ASCII NUL character to it, and pads the resulting string to the next larger integer multiple of 16 decimal bytes.

Here is a hexadecimal dump of the first 192 bytes in the PROM image file produced by the BLD_PROM session described in the preceding paragraphs.

```
C000:0000 43 6F 70 72 2E 20 31 39-39 32 20 47 45 20 46 61   Copr. 1992 GE Fa
C000:0010 6E 75 63 20 41 75 74 6F-6D 61 74 69 6F 6E 20 4E   nuc Automation N
C000:0020 2E 41 2E 20 49 6E 63 2E-5E 50 43 4D 37 31 31 00   .A. Inc. ^PCM711.
C000:0030 86 A5 50 43 4D 45 58 45-43 2E 42 41 54 00 FF 00   ..PCMEXEC.BAT....
C000:0040 05 02 0D 00 00 00 B4 40-00 00 00 00 00 00 06 C0   ........@........
C000:0050 52 20 48 45 4C 4C 4F 2E-45 58 45 0D 0A FF FF FF    R.HELLO.EXE.....
C000:0060 86 A5 48 45 4C 4C 4F 2E-45 58 45 00 FF FF FF 00   ...HELLO.EXE.....
C000:0070 02 02 55 43 00 00 6B 16-00 00 00 00 00 00 00 00   ..UC..k.........
C000:0080 02 00 A0 00 09 C0 00 00-B4 C3 95 08 00 00 00 08   ................
C000:0090 43 6F 70 79 72 69 67 68-74 20 47 45 20 46 41 4E    Copyright GEFAN
C000:00A0 55 43 20 31 39 39 32 2C-20 50 43 4D 20 43 20 56   UC 1992, PCM C V
C000:00B0 31 2E 30 30 00 39 21 46-57 32 36 42 31 00 00 00   1.00.92FW26B1....
```

The first 48 decimal bytes contain the copyright string. Note that there are no carriage return (CR; ASCII code 13 decimal) or line feed (LF; ASCII code 10 decimal) characters. They are optional. The next 48 decimal characters, starting at address **C000:0030,** contain the module header and file contents of PCMEXEC.BAT. The final 96 bytes, starting at **C000:0060**, contain the module header, executable file header, and a part of the startup module data from HELLO.EXE. The PCM toolkit release which produced HELLO.EXE is identified by its GE Fanuc version number, 1.00.

Chapter 12

GE Fanuc Support Services and Consultation

With the purchase of the C Programmer's Toolkit (IC641SWP710), GE Fanuc provides 26 hours of consultation during the first 12 months. This service is available in the form of telephone (800 - 828 - 5747) and in-person consultation sessions in Charlottesville. Consultation time is accrued in increments of 1/4 hour, with the minimum time being 1/4 hour.

Appendix A

Microsoft Runtime Library Support

The tables in this appendix list all the functions provided in Microsoft C 6.0 and Microsoft C / C++ 7.0 runtime libraries. For each function, a table entry specifies its availability for PCM C applications. Generally, availability falls into one of these categories.

1. The function is supported without restriction in all the Intel memory models supported by the PCM.

   Note that Microsoft code will not always be used for these functions. In some cases, a C preprocessor macro defined in a PCM header file will substitute a different function call. In other cases, code provided with the PCM C toolkit will replace code in the Microsoft library. These substitutions occur as a result of the order in which libraries are specified to the Microsoft linker.

2. The function may be used without restrictions in large model applications, but restrictions apply in small and medium models. In many cases, functions which take pointers as parameters are restricted in small and medium models to DS-based addresses (addresses of global or static variables) for these parameters. This is a result of VTOS having separate data and stack segments even in the small and medium models. In other cases, functions may be used **only** in large model.

3. The function is not supported in any memory model because of a major difference between the VTOS and MS-DOS operating systems or between PCM and PC hardware.

Caution

There is no enforcement of these restrictions. The user is responsible for avoiding the use of unsupported functions and for the correct use of conditionally supported functions.

Errors will occur when unsupported functions are used or conditionally supported functions are used incorrectly. The consequences range from immediate PCM lockup to intermittent or minor errors with no apparent connection to the unsupported or conditionally supported function.

Every C source file **must** include the header file where the function prototype is defined for each standard library function which it calls. This is absolutely **essential** in the small and medium memory models.

Caution

Failure to include header files where prototypes for standard library functions are defined often results in PCM lockup or unexpected operation.

Table A-1. Buffer Manipulation Functions

Function	Memory Model
memccpy memchr memcmp memcpy memicmp memmove memset	These functions are supported in all memory models. In small and medium models, they are redefined by macros. The model-independent versions below are recommended.
_fmemccpy _fmemchr _fmemcmp _fmemcpy _fmemicmp _fmemmove _fmemset	These model-independent functions are supported in all memory models and are recommended.
swab	This function is supported in large model only.

Table A-2. Character Classification and Conversion Functions

Function	Memory Model
isalnum isalpha isascii iscntrl isdigit isgraph islower isprint ispunct isspace isupper isxdigit toascii tolower _tolower toupper _toupper	These functions are supported in all memory models.

Table A-3. Data Conversion Functions

Function	Memory Model
abs labs	These functions are supported in all memory models.
atoi atol ltoa. ultoa	These functions are supported in all memory models. PCM library functions must be linked rather than Microsoft library functions.
atof ecvt fcvt gcvt strtod strtol strtoul	These functions are supported in large model without restriction. In the small and medium memory models, they may be used only for DS-based variables.
_atold _strtold	These functions are not supported in any memory model.

Table A-4. Directory Control Functions

Function	Memory Model
chdir _chdrive getcwd _getdcwd _getdrive mkdir rmdir _searchenv	These functions are not supported in any memory model.

Table A-5. File Handling Functions

Function	Memory Model
access chmod chsize filelength fstat _fullpath isatty locking _makepath mktemp remove rename setmode _splitpath stat umask unlink	These functions are not supported in any memory model.

Table A-6. Low Level Graphics and Character Font Functions

Function	Memory Model
_arc _arc_w _arc_wxy _clearscreen _displaycursor _ellipse _ellipse_w _ellipse_wxy _floodfill _floodfill_w _getactivepage _getarcinfo _getbkcolor _getcolor _getcurrentposition _getcurrentposition_w _getfillmask _getfontinfo _getgtextextent _getgtextvector _getimage _getimage_w _getimage_wxy _getlinestyle _getphyscoord _getpixel _getpixel_w _gettextcolor _gettextcursor _gettextposition _gettextwindow _getvideoconfig _getvisualpage _getviewcoord _getviewcoord_w _getviewcoord_wxy _getwindowcoord _getwritemode _grstatus _imagesize _imagesize_w _imagesize_wxy _lineto _lineto_w _moveto _moveto_w _outgtext _outmem _outtext _pie _pie_w _pie_wxy _polygon _polygon_w _polygon_wxy	These functions are not supported in any memory model.

Function	Memory Model
_putimage _putimage_w _rectangle _rectangle_w _rectangle_wxy _registerfonts _remapallpalette _remappalette _scrolltextwindow _selectpalette _setactivepage _setbkcolor _setcliprgn _setcolor _setfillmask _setfont _setgtextvector _setlinestyle _setpixel _setpixel_w _settextcolor _settextcursor _settextposition _settextrows _settextwindow _setvideomode _setvideomoderows _setvieworg _setviewport _setvisualpage _setwindow _setwritemode _unregisterfonts _wrapon	These functions are not supported in any memory model.

Table A-7. Presentation Graphics Functions

Function	Memory Model
_pg_analyzechart _pg_analyzechartms _pg_analyzepie _pg_analyzescatter _pg_analyzescattems _pg_chart _pg_chartms _pg_chartpie _pg_chartscatter _pg_chartscattems _pg_defaultchart _pg_getchardef _pg_getpalette _pg_getstyleset _pg_hlabelchart _pg_initchart _pg_resetpalette _pg_resetstyleset _pg_setchardef _pg_setpalette _pg_setstyleset _pg_vlabelchart	These functions are not supported in any memory model.

Table A-8. Stream I/O Functions

Function	Memory Model
fclose fcloseall fgetc fgetpos fgets fopen fprintf fputc fputs fread	These functions are supported in all memory models. PCM Library functions must be linked rather than Microsoft library functions.
clearerr feof ferror fgetchar fileno fputchar ftell getchar putchar	These functions are supported in all memory models. They are redefined by macros.
scanf fflush flushall	These functions are not supported in any memory model.

Function	Memory Model
freopen fseek fsetpos fwrite getc gets getw printf putc puts putw rewind sprintf ungetc vsprintf	These functions are supported in all memory models. PCM library functions must be linked rather than Microsoft library functions.
fscanf sscanf vfprintf vprintf fdopen _fsopen rmtmp setbuf setvbuf tempnam tmpfile tmpnam close creat dup dup2 eof lseek open read sopen tell umask write	These functions are not supported in any memory model.

Table A-9. Console and Port I/O Functions

Function	Memory Model
inp inpw outp outpw	These functions are supported in all memory models.
cgets cprintf cputs cscanf getch getche kbhit putch ungetch	These functions are not supported in any memory model.

Table A-10. Internationalization Functions

Function	Memory Model
localeconv setlocale strcoll strftime strxfrm	These functions are not supported in any memory model.

Table A-11. Math Functions

Function	Memory Model
acos asin atan atan2 ceil cos cosh div exp fabs floor fmod ldexp ldiv log log10 _lrotl _lrotr max min pow rand _rotl _rotr sin sinh sqrt srand tan tanh	These functions are supported in all memory models.
dieeetomsbin dmsbintoieee fieeetomsbin fmsbintoieee modf	In small and medium memory models, use only with DS-based variables. Unrestricted in large model.
cabs frexp hypot	These functions are supported in large model only.

Function	Memory Model
acosl asinl atanl atan2l bessel * cabsl ceill cosl coshl expl fabsl floorl fmodl _fpreset frexpl hypotl ldexpl logl log10l matherr _matherrl modfl powl sinl sinhl sqrtl tanl tanhl	These functions are not supported in any memory model.
_clear87 _control87 _status87	These functions are not supported in any memory model.

* Note: The Bessel functions are j0, j1, jn, y0, y1, yn, _j0l, _j1l, _jnl, _y0l, _y1l, and _ynl.

Table A-12. Memory Allocation Functions

Function	Memory Model
stackavail	This function is supported in all memory models. The PCM library function must be linked rather than the Microsoft library function.
calloc free malloc	These functions are supported in all memory models. In small and medium models, they are redefined by macros. Note that in small and medium models, **`far`** pointers must be used to access allocated buffers.
alloca _bcalloc _bexpand _bfree _bfreeseg _bheapadd _bheapchk _bheapmin _bheapseg _bheapset _bheapwalk _bmalloc _bmsize _brealloc _expand _fcalloc _fexpand _ffree _fheapchk _fheapmin _fheapset _fheapwalk _fmalloc _fmsize _frealloc _freect halloc _heapadd _heapchk _heapmin _heapset _heapwalk hfree _memavl _memmax _memsize _ncalloc _nexpand _nfree _nheapchk _nheapmin _nheapset _nheapwalk _nmalloc _nmsize _nrealloc realloc	These functions are not supported in any memory model.

Table A-13. Process and Environment Control Functions

Function	Memory Model
exit _exit	These functions are supported in all memory models.
abort assert atexit _beginthread _cexit _c_exit cwait _endthread execl execle execlp execlpe execv execve execvp execvpe getenv getpid longjmp onexit _pclose perror _pipe _popen putenv raise setjmp signal spawnl spawnle spawnlp spawnlpe spawnv spawnve spawnvp spawnvpe system wait	These functions are not supported in any memory model.

Table A-14. Search and Sort Functions

Function	Memory Model
bsearch lfind lsearch qsort	In small and medium memory models, use only with DS-based variables. Unrestricted in large model.

Table A-15. String Manipulation Functions

Function	Memory Model
strdup _fstrdup	These functions are supported in all memory models. PCM library functions must be linked rather than Microsoft library functions. Note that in small and medium models, **far** pointers must be used as parameters and return values.
strcpy strlen	These functions are supported in all memory models. In small and medium models, they are redefined by macros.
strcat strchr strcmp strcspn stricmp strlwr strncat strncmp strncpy strnicmp strnset strpbrk strrchr strrev strset strspn strstr strtok strupr	These functions are supported in all memory models. In small and medium models, they are redefined by macros. The model-independent versions below are recommended.
_fstrcat _fstrchr _fstrcmp _fstrcpy _fstrcspn _fstricmp _fstrlen _fstrlwr _fstrncat _fstrncmp _fstrncpy _fstrnicmp _fstrnset _fstrpbrk _fstrrchr _fstrrev _fstrset _fstrspn _fstrstr _fstrtok _fstrupr	These functions are supported in all memory models.
_nstrdup strerror _strerror	These functions are not supported in any memory model.

Table A-16. System Calls

Function	Memory Model
_disable _enable FP_OFF FP_SEG	These functions are supported in all memory models.
_bios_disk _bios_equiplist _bios_keybrd _bios_memsize _bios_printer _bios_serialcom _bios_timeofday bdos _chain_intr _dos_allocmem _dos_close _dos_creat _dos_creatnew _dos_findfirst _dos_findnext _dos_freemem _dos_getdate _dos_getdiskfree _dos_getdrive _dos_getfileattr _dos_getftime _dos_gettime _dos_getvect _dos_keep _dos_open _dos_read _dos_setblock _dos_setdate _dos_setdrive _dos_setfileattr _dos_setftime _dos_settime _dos_setvect _dos_write dosexterr _harderr _hardresume _hardretn int86 int86x intdos intdosx segread	These functions are not supported in any memory model.

Table A-17. Time Functions

Function	Memory Model
asctime clock ctime difftime ftime gmtime localtime mktime _strdate strftime _strtime time tzset utime	These functions are not supported in any memory model.

Table A-18. Variable Length Argument List Functions

Function	Memory Model
va_arg va_end va_start	These functions are supported in all memory models. They are defined in the header file **`stdarg.h`**.

Appendix B PCM Commands

The PCM includes a command interpreter which is similar in principle to the MS-DOS command line interpreter or the UNIX shell. PCM commands provide complete control for loading and storing applications, and for executing them.

Accessing the Command Interpreter

The PCM command interpreter is connected by default to PCM serial port 1 whenever the PCM is not configured by Logicmaster 90 software in CCM ONLY mode and is not executing an application program. The following discussion assumes that you are trying to access the command interpreter through serial port 1 using the TERMF terminal emulation program. TERMF is described fully in chapter 2, section 3 of *Series 90 Programmable Coprocessor Module and Support Software User's Manual*, GFK-0255D or later.

When a PCM is configured in PCM CFG mode using Logicmaster 90 software and there are no files stored in it, the command interpreter will be connected to serial port 1 whenever the PCM is reset by holding the restart button for more than five seconds (a hard reset). Pressing the Enter key displays a "**>**" prompt from the interpreter when it is active. Pressing Enter repeatedly adds another "**>**" prompt on the same line each time you press it.

Depending on the Logicmaster 90 configuration for the PCM, the MegaBasic interpreter may start at power-up or a reset. MegaBasic prints a startup banner message (by default to port 1) whenever it starts. When you see the startup message and a **Ready** prompt, you can type **bye** and press the Enter key to exit from MegaBasic to the command interpreter. If you see the startup message but no **Ready** prompt, MegaBasic is running a program. You can usually stop the program by pressing Ctrl–C (hold the Ctrl key down while typing "C").

If you cannot access the command interpreter after trying the procedures described above, use the Logicmaster 90 configuration software to check the PCM configuration. If a configuration has been stored to the PLC, load it to Logicmaster software and then check the PCM configuration mode to be sure it is either BASIC, BAS / CCM, PCM CFG, or PROG PRT. If the PCM mode is not one of these, change it and store the new configuration to the PLC. If there is no PLC configuration, create one with the PCM configured to PCM CFG mode and then store it to the PLC.

As a last resort, try powering off the PLC, disconnecting the PCM battery, shorting the PCM battery terminals for at least ten seconds, powering on the PLC, and then reconnecting the battery. If there is no MegaBasic startup banner or command prompt, and you are sure the PCM configuration mode is correct, refer to chapter 6, *Troubleshooting Guide*, in the *Series 90 Programmable Coprocessor Module and Support Software User's Manual*, GFK-0255D or later.

Interactive Mode

When the PCM connects you to the command interpreter after power up or a reset, you should see a this prompt:

```
->
```

When you return to the command interpreter from MegaBasic, you may not see a prompt on your screen immediately, but pressing the Enter key should display a "**>**" prompt. At this point, the interpreter is in its default mode, which is used to communicate with the PCM development software package, PCOP. Default mode does not respond to you with text messages, nor does it echo the keys you type back to your screen. You must switch to interactive mode by typing two exclamation points ("**!!**") and pressing the Enter key. This message will appear:

```
   INTERACTIVE MODE ENTERED
type '?' for a list of commands
```

To display the list of PCM commands, type a question mark ("**?**") and press the Enter key. If you are using PCOP, you need to type three exclamation points ("**!!!**") and then press the Enter key in order to return to PCOP mode. PCOP cannot communicate with the command interpreter while it is in interactive mode.

Caution

When using Megabasic, make sure all your programs have been saved to your computer (the PC: device) before attempting to use the command interpreter.

All PCM commands begin with a single letter which identifies the command. The complete command is an ASCII string, terminated by a CR character. Command arguments are separated from the command character and each other by one or more spaces.

NOTE

In PCM firmware versions prior to 3.0, command letters used in PCM batch files (see appendix B), were **required** to be upper case. When using PCM commands in batch files which may be used with an earlier firmware version, you should use upper-case characters exclusively to avoid errors.

Notation Conventions

Arguments are shown as symbolic names within angle brackets (**< >**). For example, **<file_name>** represents a string of ASCII characters containing the name of a file, **<pcm_filename>** represents a string of ASCII characters containing the name of a PCM file, <**led_use_code**> represents two ASCII characters containing a one byte hexadecimal value, etc.

Optional arguments are shown in square brackets ("**[ ]**"). They may be omitted; all other arguments are required. The notation **[<option> ...]** indicates that zero or more instances of **<option>** may be used.

A vertical bar separates two or more valid selections where one value must be specified. For example, 1 | 2 indicates you may choose either 1 or 2.

Commands

PCM commands are summarized in the following table:

Table B-1. PCM Commands

Command	Description
L	Load a file from the PC.
S	Save a file to the PC.
D	Show a Directory of files in memory.
X	eXterminate (delete) a file.
R	Run an executable file.
K	Kill a running task.
C	Clear the PCM.
@	Execute a batch file.
F	Show available memory.
G	Get PCM memory ID.
H	Get the PCM revision number.
B	Configure a user LED.
U	Reconfigure the PCM.
M	Create a memory module.
PT	Show PCM task information.
PC	Show PCM config errors.
PM	Show reset type and mode.
PL	Show the location of the PCM.
PD	Dump the state of the PCM just before the last reset to a PC file.
!!	Enter INTERACTIVE mode.
!!!	Exit INTERACTIVE mode.

The following commands are also available. The I (Initialize a device) command is often used to set the communication parameters of PCM serial ports. The others are seldom used except by PCOP.

Table B-2. PCM Commands

Command	Description
I	Initializea device.
J	Format the ROM: device (PCM 301 only).
O	Get LED configuration.
Q	Set protection level.
V	Verify a file.
W	Wait for a background task.
Y	Set upper memory limit.

The remainder of this appendix provides detailed descriptions of the commands listed in the preceding tables. The commands are presented in alphabetical order.

@ (Execute a Batch File)

Format: **@<file_name>**

This command executes the PCM batch file **<file_name>**. No intervening space is permitted between the @ command and the file name. These examples show how the @ command is used. The file extension is optional; in the last example, MYFILE.BAT is executed. If no device is specified, as in the first and last examples, RAM: is assumed.

```
@MY.BAT
@PC:A:\MYDIR\MY.BAT
@MYFILE
```

These errors can be returned:

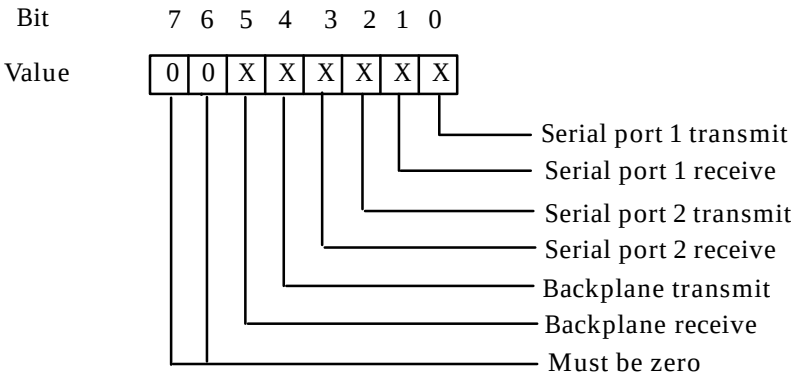
```
File not found <file_name>
Illegal module type <file_name>
```

See appendix C, *Batch Files*, for more information on PCM batch files.

B (Configure LEDs)

Format: **B <led_number> <led_use_code> [<task_number>]**

This command configures either of the bottom two PCM LEDs (USER1 and USER2). The LED number can be either of the ASCII characters ”1” or ”2”. The LED use code is a two-digit ASCII hexadecimal code that specifies a configuration byte for the LED. Binary values for the LED use code are as follows:



Combine the bits for the desired LED action into a single byte value in hexadecimal format. For example, to blink LED USER1 when characters are transmitted or received on serial port 2, use binary code 00001100. This is equivalent to 0C hexadecimal, so the command is:

```
B 1 0C
```

The task number, if specified, is an ASCII hexadecimal digit that specifies which task will control the indicated LED. The task number must be the number of a valid task (0–0F hexadecimal). When an LED is assigned to a task, the LED use code must be specified as 40 hex. To configure LED 1 to be controlled by task 7, use:

```
B 1 40 7
```

Task 7 will then be able to change the behavior of LED 1. A second B command may be used specify a default communication event or events which will flash the LED before task 7 programs it.

C (Clear the PCM)

Format: **C**

This command deletes all RAM disk files on the PCM, including UCDF configuration data. The C command returns an error:

```
Module in use <file_name>
```

if any files are in use. When this occurs, the PCM must be put in factory mode (by holding the restart / reset button for more than five seconds or issuing a hard reset COMMREQ message from the PLC ladder program) before it can be cleared.

D (file Directory)

Format: **D [<option>]**

This command prints the names of the files stored in the PCM RAM disk or other file devices. It returns no errors. A single letter **<option>**, separated by a space from the D command, may be used. The table below shows the data returned by this command and its options.

Option	Description
D	The D command used alone shows the names of non-hidden files in the PCM RAM disk.
D H	This command option shows all files, hidden and non-hidden, in the PCM RAM disk. Hidden files may include files loaded to the PCM using the **Hidden** attribute as well as file data blocks appended to files created by PCM applications.
D P	This command option shows files in the PCM system EPROM. These files provide VTOS functionality.
D R	This command option shows files in the PCM option EPROM. These files provide functionality such as MegaBasic, CCM, etc.

When the D command is invoked from INTERACTIVE mode, an entry point address is shown for executable (.EXE) files:

```
> D

HELLO.EXE     0616:00A0
```

The entry point is displayed as a segmented FAR address. In the example above, HELLO.EXE is a C program which was created on a PC and then loaded to the PCM RAM disk using the L (Load) command. The entry point is useful for debugging medium and large model PCM applications.

F (Show Free Memory)

Format: **F**

In interactive mode, this command displays the amount of free PCM memory as two decimal numbers:

```
Total available memory is xxxxxx bytes
Largest available block is yyyyyy bytes
```

The first is the total of all available memory. The second is the size of the largest free memory block. Both sizes are expressed in bytes. No errors are returned.

G (Get Hardware ID)

Format: **G**

This command returns the ID number of the PCM hardware configuration. The value is an ASCII string containing two hexadecimal digits which specify the ID. One of the following codes is returned:

Code	Description
00	Series 90-70 PCM with no daughter board.
1D	Series 90-70 PCM with a 512K daughter board (640K bytes total).
1E	Series 90-70 PCM with a 256K daughter board (384K bytes total).
1F	Series 90-70 PCM with a 128K daughter board (256K bytes total).
1C	Series 90-70 PCM with a 64K daughter board (192K bytes total).
FF	Series 90-30 PCM model IC693PCM300 (160K bytes).
FE	Series 90-30 PCM model IC693PCM301 (192K bytes).
FC	Series 90-30 PCM model IC693PCM311 (640K bytes).
80	Graphics Display Coprocessor Module with a video daughter board.
81	Series 90-70 Alphanumeric Display Coprocessor Module.
82	Series 90-30 Alphanumeric Display Coprocessor Module.

H (Get PCM Firmware Revision Number)

Format: **H**

This command returns the firmware release number of the PCM. The ASCII string returned by the PCM contains a single digit for the major revision number, a period, and two digits for the minor revision number. For example:

```
Software revision number is 3.00
```

I (Initialize Device)

Format: I <device_name> <device_initialization_string>

This command sends the specified initialization string to the specified device. Currently, the two serial devices, COM1 and COM2, and the CPU device support this command.

A space character is required between the device name and initialization string. The parameters in **<device_initialization_string>** must occur in the order listed in the table below with no intervening spaces. Any number of parameters may be omitted at the right end of the string. Parameters to the left of the last one may be omitted, but all the surrounding commas must be included. Omitted parameters retain their previous settings..

Device	Initialization String
COM1: COM2:	**<baud_rate>,<parity>,<data_bits>,<stop_bits>,<flow_contr ol>, <physical_interface>,<duple x_mode>,<delay_value>, <typeahead_size>** where: **<baud_rate>** = 300, 600, 1200, 2400, 4800, 9600, 19200*, or 38400 – the number of bits per second. Note that 38,400 baud is supported only by the Series 90-70 PCM, and only for RS-422 or RS-485 port configurations. **<parity>** = O, E, N* - the type of parity checking: Odd, Even, or None. **<data_bits>** = 7 or 8* - the number of data bits per character. Use 8 unless text with 7 bit characters will be the *only* data transferred. **<stop_bits>** = 1* or 2 - the number of stop bits per character. The normalselection for 300 baud and higher is 1. **<flow_control>** = H*, S, or N - the flow control method: Hardware (CTS / RTS), Software (X-ON, X-OFF) or None. **<physical_interface>** = 232*, 422, or 485 - the physical connection protocol for the port: RS-323, RS-422, or RS-485. RS-422 is equivalent to RS-485. All Series 90-30 PCMs support RS-232 only on COM1. IC693PCM300 supports RS-422 / 485 only on COM2. With hardware flow control, RTS is turned on when the port is ready to transmit. Then, transmission begins when CTS becomes active. RTS remains on until **<delay_value>** expires after the last character is sent. With software or no flow control, RTS is not turned on, and transmission begins immediately. **<duplex_mode>** = 2, 4*, or p - the type of physical connection: 2 = half duplex (2 wire for RS-422 / 485), 4 = full duplex (4 wire for RS-422 / 485), p = point-to-point. **Available in PCM firmware version 3.00 or later.** In **point-to-point** mode: • The receiver for the specified port is always enabled. • When **<physical_interface>** = 422 or 485, all RS-485 line drivers for the specified port are enabled when the command is executed and remain on continuously. * Default selection.

Device	Initialization String
COM1: COM2: (Continued)	**<duplex_mode> (Continued)** In **full duplex** mode: • The receiver for the specified port is always enabled. • When **<physical_interface>**= 422 or 485, the RS-485 line drivers for RTS and transmitted data outputs on the specified port are turned on immediately before transmitting and remain on until **<delay_value>** expires after the last character is sent. At all other times, these drivers are in their high-impedance state (tri-stated). In **half duplex** mode: • The receiver for the specified port is disabled immediately before transmitting and remains off until **<delay_value>** expires after the last character is sent. • When **<physical_interface>** = 422 or 485, the RS-485 line drivers for RTS and transmitted data outputs on the specified port are turned on immediately before transmitting and remain on until **<delay_value>** expires after the last character is sent. At all other times, these drivers are in their high-impedance state (tri-stated). **<delay_value>** = the time in milliseconds between the end of the last outgoing character and the time RTS is turned off (if applicable), RS-485 line drivers are tri-stated (if applicable), the receiver is enabled in half duplex mode (if applicable), and WAIT mode output statements complete execution. Default = 0. **Available in PCM firmware version 3.00 or later.** **<typeahead_size>** = the typeahead buffer size in characters for the port. The port can accept up to one less than this number of characters without overflow before an application reads the port. When overflow occurs, any additional characters will be lost. Any size in the range 64 – 32750 bytes may be specified, but the maximum may be limited by available system memory. Default = 320. **Available in PCM firmware version 3.00 or later.**
CPU:#5	**<PLC_access_password>,<disable_clock_sync>** where: **<PLC_access_password>** = the PLC access password for privilege level 2 or higher. If passwords are enabled in the PLC CPU and the PLC has passwords at level 2 and higher, the PCM will be unable to read or write PLC memory until the PCM sends a valid password. Passwords are case sensitive, and valid passwords may have upper case letters, numbers, and underbar ('_') characters only. If an empty string is specified for **<PLC_access_password>** , a password consisting of eight NUL characters will be sent to the PLC CPU. There is no default. **<disable_clock_sync>** = N - disables backplane messages the PCM normally sends once per second to synchronize its internal time of day with the PLC CPU. Any character other than 'N' or 'n' enables clock synchronization. **Available in PCM firmware version 4.03 or later** Some applications may be sensitive to the impact that clock synchronization messages have on PLC sweep time or backplane message rates. If these issues are more important than time of day accuracy, use this option. Default = synchronization enabled.

Examples:

```
I COM1: 9600,,,,S
I COM2: 38400,O,8,1,S,485,2,10,1024
```

The first example sets the port 1 data rate to 9,600 baud and selects software flow control. Selections for parity, data bits, and stop bits are the omitted items between the four consecutive commas; they are unchanged.

The second example sets port 2 for RS-485 two wire half duplex operation at 38,400 baud, odd parity, 8 data bits, and one stop bit; using software flow control, a ten millisecond time delay, and a 1024 character typeahead buffer.

```
I CPU:#5 PASSWD
I CPU:#5 MYPASWD,N
I CPU:#5 ,Y
```

The third example sets the PCM privilege to the access level protected by the password "PASSWD".

The fourth example sets the PCM privilege to the access level protected by "MYPASWD" and also disables PCM clock synchronization.

The last example re-enables PCM clock synchronization but has no effect on PLC access level.

J (Format EEROM Device)

Format: **J ROM:**

The Format command causes an electrically erasable ROM (EEROM) device installed in a PCM 301 to be erased and formatted as the file device **ROM:**. Once the EEROM has been formatted, files can be loaded to it and MegaBasic programs stored to it just as they are in **RAM:**. Note that files may be copied to the **ROM:** device only from the PCM RAM disk. Only the PCM 301, GE Fanuc catalog number IC693PCM301, supports an optional EEROM device.

Attempting to format an invalid device produces this message:

```
Unknown device <name>
```

C language executable (EXE) files may not be executed from EEPROM. They may, however, be stored as relocatable files in EEPROM and then loaded to **RAM:** for execution. Since EEPROM files must be copied from **RAM:**, the PCM must be tricked into loading EXE files to **RAM:** in relocatable form. The trick requires renaming the executable file in the PC so that it no longer has the .EXE extension.

For example, to save MYPROG.EXE in EEPROM, first rename the PC file MYPROG.RAM. You could use any file extension other than .EXE. Then, use these PCM commands to save the EXE file to EEPROM. More information on the L (Load) and S (Save) commands may be found in later sections of this appendix.

```
L MYPROG.RAM
S RAM:MYPROG.RAM ROM:MYPROG.EXE
```

The following commands may be placed in a PCMEXEC.BAT batch file to load and run the program whenever the PCM is reset or powered on. Note that an old copy of the program in RAM (if there is one) is replaced automatically by the L (Load) command.

```
L ROM:MYPROG.EXE
R MYPROG.EXE
```

K (Kill a Task)

Format: **K <task_id>**

This command stops the specified task and frees the resources it was using. The task is unlinked from all associated modules (all link counts are decremented). Timers used by the task are cancelled, pending ASTs are discarded, pending I/O is aborted, open files are closed, and memory used by the task is returned to the operating system.

The task ID argument must be in the range of 4–0F hexadecimal. If it is not, the PCM responds with the error message:

```
Cant terminate task.
```

L (Load)

Format: **L[<options>] <pc_filename> [<pcm_filename>]**

This command directs the PCM to load the file specified by **<pc_filename>** to **<pcm_filename>** in the PCM RAM disk. The file names are not case sensitive. If the optional **<pcm_filename>** is omitted, the PC filename will be used, but without any device or file path prefix. If the file already exists in the PCM, it will be overwritten.

Two optional qualifiers may be specified with the load command: display mode and protection mode. The display mode determines whether or not the file will be included in a module directory listing. The two modes are normal (N) and hidden (H). Normal mode is the default.

The protection mode is used to determine whether the PCM file will be volatile (V), semi-volatile (S) or protected (P). For certain file types (for example, EXE files, described below), the protection level is fixed at P by default, and a protection option in the load command is ignored. Data files are volatile by default, but this may be overridden by the load command.

If options are used in the load command, they follow the command directly, with no intervening spaces. For example, **LH** is used to load a hidden module, and **LHP** is used to load a protected hidden module.

Possible errors are:

```
File not found <file_name>
Illegal module type <file_name>
Insufficient memory
```

The **<pcm_filename>** may contain at most an eight-character file name, a dot character, and a three-character file extension (8.3 or "eight dot three" format).

The **<pc_filename>** format is determined by the PC file system. The PC file name may optionally begin with a path and/or device name. If there is no device name, the default device, "PC:", is assumed.

The DOS file system also has the 8.3 filename format restriction, exclusive of the device and path prefix. A PC disk drive may be included in **<pc_filename>**; if a disk drive is specified, the PC: device must also be explicitly specified.

Other files systems may use different **<pc_filename>** formats. The last example here assumes the UNIX file system.

```
L MYFILE.DAT
L PC:A:MYFILE.DAT
L PC:C:\MYDIR\MYFILE.EXE
L /usr/abc/this.is.a.funny.name MYFILE.DAT
```

If **<pc_filename>** has the extension EXE, and the file begins with a valid MS-DOS relocatable EXE file header, the PCM will attempt to convert the file to an absolute executable image in RAM. The protection mode for EXE files is Protected, regardless of any options used with the load command.

See the Q (Set Protection Level) command for a special restriction regarding EXE files using the Intel large memory model.

M (Create a Memory Module)

Format: **M <module_name> <size>**

The create memory module command creates a PCM data module using the specified **<module_name>** and **<size>** arguments. The module **size** is interpreted as a hexadecimal number of bytes.

The command has no effect if the module already exists. If the module does not exist, it will be created and initialized to all zeros. No checksum protection will be applied to the module; it may be freely read and written. The location of the module may change after a reset, but its contents will remain the same.

O (Get LED Configuration)

Format: **O**

This command is used to return the LED configuration for the PCM. Two words of binary data are returned. The first word holds the configuration of LED 1, and the second holds the LED 2 configuration. However, TERMF does not display the binary values correctly.

Note

The O command is provided mainly for PCOP and does not return meaningful data when invoked from interactive mode.

P (Request Status Data)

Format: **P<status_type>**

The **<status_type>**, a second letter, specifies the type of status data requested. No intervening spaces are permitted. The information returned is explained in this table:

Status Type	Description
PC	Show how the status of the PCM configuration. If the last configuration completed without errors, the PCM returns the prompt "**>**". If there were errors, the PCM returns an error string.
PD	Dump the operating status of PCM at the most recent PCM reset. When a soft reset occurs (the reset / restart pushbutton is held down for less than five seconds) or a PCM resets itself because of certain fatal software errors, it saves the contents of its task control blocks plus the top 64 words of the stack for the task which was executing at the time and the top 32 words of all other tasks. The PD command causes the PCM to write this information to a binary file called **PCMDUMP.OUT** on the PC default directory. This data can be formatted as text with the **PCMDUMP.EXE** utility or the MegaBasic program **PCMDUMP.PGM**. The information is useful when the PCM unexpectedly locks up or resets itself. Hard resets (holding the button down for ten seconds) have no effect on the saved task control block and stack data from the most recent soft reset, but cycling PLC power off and on will corrupt it.
PL	Show the PCM rack / slot location. The PCM returns two ASCII digits. The first digit specifies the rack number, and the second digit specifies the slot number. The ASCII digits may be followed by a string that contains the CPU ID. If the PLC CPU does not have an ID, a string consisting of just the ASCII NL character is returned. If the PCM cannot establish communication with the CPU, the message "NO CPU" is sent.
PM	Show the type and mode of the most recent PCM reset. The PCM returns two ASCII digits. The first digit specifies the type of the most recent PCM reset: 0 = Powerup reset. 1 = Soft reset. 2 = Hard reset, including a COMMREQ hard reset. 3 = ACFAIL reset. 4 = Reset caused by receipt of new soft switch data. 5 = Internal software error reset. 6 = COMMREQ soft reset. The second digit specifies the type of configuration data used during the most recent reset: 0 = User configuration (UCDF) data. 1 = Factory default configuration data. 2 = Logicmaster 90 configuration. 3 = A combination of Logicmaster 90 and factory default data.
PT	Show the status of PCM tasks. For each active task, the PCM returns the task number and the names of the task's code and environment modules.

Q (Set Protection Level)

Format: **Q <file_name> <protection_level>**

This command is used to change the protection level of a module or modules on the PCM RAM disk.

Level	Description
0	Unprotect the file: the file is not checksum protected and may be freely written. The checksum is not verified on powerup or reset.
1	Protect the file: a checksum is calculated for it, and it may no longer be written to. On powerup or reset, the checksum of the module is verified and, if it is not correct, the module is discarded.

Note that when a C executable (EXE) file is loaded the the PCM RAM disk, its protection mode is set by default to Protected. EXE files using the Intel large memory model and produced by the Microsoft linker have their code and date segments intermixed. There is no information in a large model EXE file itself about the locations and sizes of its data segments. The PCM assumes that all the code and data segments should be protected. Consequently, any changes to the data in these segments (static data in C parlance) will cause a checksum verification failure at the next reset of the PCM.

The Q command must be used to unprotect large model EXE files loaded to the PCM RAM disk.

R (Run)

Format: **R <file_name> [<option> ...] [<command_data_string> ...]**

This command causes the PCM to run the executable file specified by **<file_name>**. The command line may include zero or more options and zero or more data strings. Options and data strings may be intermixed. The following options are available:

Option	Description
>outchnl	Redirect standard output to the channel specified by outchnl. Choices are ***COM1:**, **COM2:**, **RAM:<pcm_filename>**, **ROM:<pcm_filename>**, and **PC:<pc_filename>**, where **<pcm_filename>** and **<pc_filename>** are the names of PCM RAM disk and PC files, respectively. A device must be explicitly specified for files; the colon is required. The **ROM:** device is available only in the PCM 301, GE Fanuc catalog number IC693PCM301. A **<pc_filename>** may contain a PC device and / or file path specification: **R MYFILE.EXE >PC:C:\MYDIR\MYFILE.OUT**
<inchnl	Take standard input from the channel specified by **inchnl.** Choices are identical to the ones for the **>outchnl** option.
?errchnl	Redirect standard error output to the channel specified by **errchnl.** Choices are identical to the ones for the **>outchnl** option.
/ Sxxxx	Use a stack size of xxxx hexadecimal bytes. If the specified value is greater than the size from the executable file header (specified by the STKMOD utility), it will override the file header value. When the / S option is not used and the file header value is zero, the default stack size is 320 (800 decimal) bytes.
/ Dxxxx	Allocate xxxx hexadecimal bytes of data space to the task. This option is ignored for EXE files using the Intel large memory model. Its primary use is to limit the memory allocated to MegaBasic, reserving the balance for the PCM RAM disk. Applications using this option must provide their own mechanism to determine the location and size of the allocated memory.
/ Ex	Specify the executable task type. The default is **E1** (priority based); **E2** (time slice) is also valid. When **/E2** is specified but no **/T** option is included, the default time slice value is 10 milliseconds. When a priority based task runs, it executes until it is blocked, suspends itself or is pre-empted when a higher priority task becomes ready to run. When a time-slice task runs, it continues until its allocated time expires, it is blocked, it suspends itself, or it is pre-empted when a priority based task with higher priority becomes ready to run.
/ lx	Use a specified task ID value in the range 4 – 0F hexadecimal; by default the largest (lowest priority) unused value. For priority based tasks, smaller task ID values have higher priority. When there are two or more time-slice tasks, they run in round-robin fashion in the order of their ID values. The time-slice task with the lowest ID value runs first, followed by others in the order of increasing ID value. We recommend that all priority based tasks have higher priority than any time-slice task.
/ Txx	Allocate an execution time slice of xx hexadecimal milliseconds. Any value from 05 to FA (250 decimal), inclusive, may be specified.
/ Mname	Link the task to memory module **name** . The names of one or more memory modules are available to C applications through the PCM **modc/modv** mechanism.
/ B	Run the task in background mode. If the task and the PCM command interpreter share a serial port for **stdin**, **stdout** or **stderr,** the command interpreter remains in control of the port.
/ K	Keep the task's environment block in memory after task termination.

* Default selection.

Any strings in the command line which do not begin with the special characters (”**>**”, ”**<**”, ”**?**”, or ”**/**”) are assumed to be command data strings. They are passed to the executable program for processing. C language applications can use the standard **argc/argv** mechanism to access them.

If the file specified by the R command is not present in the PCM RAM Disk, the PCM attempts to load it from the default device, ”PC:”, using the specified file name. If it cannot find the file in either device, an error message is returned.

Errors that can be returned are:

```
Module not found <file_name>
File not found <file_name>
Insufficient memory
```

S (Save)

Format: **S <pcm_filename> [<pc_filename>]**

The Save command causes a file named **<pcm_filename>** in the PCM RAM disk to be saved to a PC file. If the optional **<pc_filename>** is omitted, the PCM filename will be used, and the file will be saved in the current directory of the current drive. If the file does not already exist on the PC, it is created; otherwise the existing PC file is overwritten. The **<pc_filename>** may include a PC disk drive and / or file path, as described above for the L (Load) command.

The **<pcm_filename>** may contain at most an eight-character file name, a dot character, and a three-character file extension (8.3 or ”eight dot three” format).

The **<pc_filename>** format is determined by the PC file system. The MS-DOS file system has the same 8.3 filename format restriction, exclusive of the device and path prefix.

The Save command is also used to copy files from the RAM disk to the **ROM:** device in the PCM 301, GE Fanuc catalog number IC693PCM301. This is the only mechanism for transferring files to the **ROM:** device.

EXE files which have been loaded to PCM RAM no longer contain relocation information. They cannot be saved to PC files. For information on saving EXE files to the ROM: device, see the J command.

Possible errors are:

```
Module not found <file_name>
Cant save module <file_name>
```

U (Reconfigure the PCM)

Format: **U <configuration_file>**

This command reconfigures the PCM according to the specified **<configuration_file>**. If any of the modules specified in the configuration file are missing, or if errors are encountered while initializing the new configuration, the PCM is placed in its factory default configuration.

The **<configuration_file>** argument must be either **FDEF** (factory) or **UCDF** (user). UDCF configuration data is stored only by PCOP. Any other file name results in one of these error messages:

```
Module not found <file_name>
Illegal module type <file_name>
```

V (Verify a File)

Format: **V <file_name>**

The V command causes the PCM to verify the checksum of the specified file on the PCM RAM disk. The file must previously have been protected by using the PCM Q (Set protection level) command. If the checksum calculated for the file matches the checksum stored in it, the PCM returns just the "**>**" prompt. If the checksums do not match, the PCM prints this error message:

```
Invalid file <file_name>
```

followed by the "**>**" prompt.

The Q command is used provide checksum protection for files.

W (Wait)

Format: **W <time>**

The WAIT command causes PCM command interpreter to wait for the specified time, in seconds, before initiating or responding to any activity on the serial ports or **REM:** (remote) device. After the specified time, the PCM prints the "**>**" prompt.

This command is provided to allow tasks running in background mode to access the PC file server. Since the PCM command interpreter and file server usually share the same serial port, the command interpreter has to be kept from using the port while the background task is using the file server. This is not a problem with tasks run in foreground mode, because the command interpreter is suspended until the foreground task completes.

X (eXterminate file)

Format: **X <file_name>**

This command deletes a file named **<file_name>** in the PCM RAM disk.

Possible errors are:

```
Module in use <file_name>
Module not found <file_name>
```

Caution

The specified file is deleted immediately. There is no confirmation prompt, nor is there any method for recovering a deleted file.

Y (Set Upper Memory Limit)

Format: **Y [<limit>]**

PCM memory may be divided between the operating system and one or more applications. Setting a limit on the memory used by the operating system causes it to ignore all memory above the limit. It will never load programs or allocate memory buffers there. Application programs can determine the limit with VTOS and access memory above the limit through the use of pointers or absolute addresses.

The optional **<limit>** argument is the amount of memory, in 16 byte paragraphs, to be retained by the operating system. It is specified as a hexadecimal value and must be at least 800 (32K bytes), to leave space for operating system data. If the specified value is too small or exceeds the total amount of memory on the PCM, this error message is returned:

```
Insufficient memory
```

If the command is entered with no argument, the operating system uses all the RAM on the PCM, and the **Get_mem_lim** utility will indicate that no limit has been set. When a limit is set, it does not actually take effect until the PCM is reset.

Appendix C Batch Files

Overview

The PCM supports batch files similar to those used with MS-DOS. You can specify a batch file to be executed interactively. In addition, you can create batch files which are executed automatically when power is applied or a soft reset occurs, or when a hard reset occurs. These files must be named PCMEXEC.BAT and HARDEXEC.BAT, respectively.

PCM batch files may consist of any number of commands. Each command must end with the ASCII CR (carriage return) character. CR may be followed optionally with the LF (line feed or newline) character.

All the commands described in appendix B, *PCM Commands*, may be used in batch files. Unlike MS-DOS, there are no commands, such as IF, ECHO, or GOTO, which work only in batch files.

Caution

In PCM firmware versions prior to 3.0, command letters used in PCM batch files were required to be upper case. If you are creating a batch file which may be used with an earlier PCM version, you should use upper-case characters exclusively to avoid errors.

Creating Batch Files

You can create batch files with any text editor which produces standard ASCII text files. Suppose you want to create a simple batch file that starts MegaBasic. First, create a PC file called **TEST.BAT**, which contains the single line:

```
R BASIC.EXE
```

After saving the file, invoke TERMF on your PC and then enter the PCM command interpreter interactive mode as described in appendix A of this document. Load the batch file to the PCM by typing:

```
L TEST.BAT
```

followed by the Enter key.

Caution

Do not attempt to load batch files to the PCM using the MegaBasic LOAD command. The MegaBasic LOAD command converts files to MegaBasic program format, which is not understood by the PCM command interpreter. Using the MegaBasic LOAD command for batch files will prevent them from executing as expected.

An alternative method of creating batch files directly in the PCM is to use MegaBasic. The following sequence of commands may be entered at the **Ready** prompt to create our example **TEST.BAT** in the PCM RAM disk and then exit from MegaBasic.

```
Ready
open #5, "ram:test.bat"
Ready
print#5, "R BASIC.EXE"
Ready
close #5
Ready
bye
```

Running Batch Files

To run the batch file created by either method of the previous section, type **@TEST** and press the Enter key.

You should see the command in **TEST.BAT** followed by the MegaBasic startup banner, indicating that the command interpreter executed the command to run MegaBasic. If you type **BYE** again, you should once again be communicating with the command interpreter in interactive mode. Verify this by pressing the Enter key; note that the "**>**" prompt appears on a new line.

PCMEXEC.BAT Files

When the PCM powers up or a soft reset occurs, the operating system looks for a file named **PCMEXEC.BAT** in the RAM disk. In PCM 301 modules, the ROM: device is also searched for PCMEXEC.BAT. If it is not found, and the PCM has been configured by Logicmaster 90 in BASIC or BAS/CCM mode, a new one is created. This file contains a single R (Run) command which instructs the command interpreter to allocate a specified block of PCM RAM to MegaBasic, to send a message to MegaBasic to execute a program named BASIC.PGM, and then to run the MegaBasic interpreter. If BASIC.PGM is found, it is then executed.

When the command interpreter starts, it executes the commands in PCMEXEC.BAT, just as the MS-DOS command interpreter uses the AUTOEXEC.BAT file when MS-DOS is booted. However, PCMEXEC.BAT is not executed following a hard reset.

HARDEXEC.BAT Files

When a hard reset occurs, the operating system looks for a file named **HARDEXEC.BAT** in the RAM disk. If this file is not found, and the PCM has been configured for BASIC or BAS/CCM mode, a new HARDEXEC.BAT created. It contains an R (Run) command which allocates a block of memory to MegaBasic and then starts the MegaBasic interpreter. In this case, no MegaBasic program name is specified; MegaBasic starts in command mode.

User-Installed PCMEXEC.BAT and HARDEXEC.BAT Files

You can create your own version of PCMEXEC.BAT and/or HARDEXEC.BAT, and load them to the PCM RAM disk. The commands you put in your PCMEXEC.BAT will control the PCM whenever it powers up or a soft reset occurs. Similarly, commands in your HARDEXEC.BAT control the PCM when a hard reset occurs. Use your computer and any text editor which produces ASCII text files to create these files. Then use the L (Load) command, described in appendix A, *Microsoft Runtime Library Support*, to load them to the PCM RAM disk.

If it exists, PCMEXEC.BAT is always run on power-up and a soft reset, regardless of whether or not PCOP has stored User Configuration Data (UCDF) to the PCM. Although PCMEXEC.BAT can be thought of as a configuration tool, its function is different from the UCDF. A UCDF can define the entire operating environment of the PCM, while PCMEXEC.BAT is limited to defining the environment for application tasks. In addition, UCDF data is processed much earlier on the reset or power-up process than PCMEXEC.BAT.

Caution

Be very careful when attempting to use both a PCMEXEC.BAT file and UCDF configuration data. There are subtle interactions between them which can prevent the PCM from operating as expected.

The most common use of the PCMEXEC.BAT file is to run application programs. Batch file commands can also be used to configure the user LEDs on the PCM and set the serial port communication parameters, as described in appendix B, *PCM Commands*.

Appendix D PCM C Directories and Files

During installation of the Series 90 PCM C toolkit, these directories and files are created on your computer's hard disk.

Table D-1. PCM C Directories and Files

Directory	File	Purpose
\PCMC	AAREADME AUTOEXECBAT AUTOEXECBAK BLD_PROM.EXE BLD_PROM.MSG CC.600 CC.BAT CC.MVC CLINKK.600 CLINK.BAT CLINK.MVC DOSC.BAT PCMC.BAT PCMDUMP.EXE PCMDUMP.MSG STKMOD.EXE STKMOD.MSG V6_BLD/BAT V7_BLD.BAR VC1_BLD.BAT	How to install this software; this list of files. If INSTALL replaces \AUTOEXEC.BAT Utility program for creating EPROM images. Message file for BLD_PROM.EXE. MS-DOS batch file for compiling one C source. MS-DOS batch file for creating a PCM .EXE from one object. Sets LIB and INCLUDE environment variables for MS-DOS compile and link. Sets LIB and INCLUDE environment variables for PCM compile and link. Utility program for diagnosing PCM task states. Message file for PCMDUMP.EXE. Utility program for setting PCM task stack size. Message file for STKMOD.MSG.

Directory	File	Purpose
\PCMC\EXAMPLES	ALARM.C	C source from text of chapter 6.
	APP_MOD.H	
	AST.H	C header file from text of chapter 7.
	AST1.C	C source file from text of chapter 7.
	AST2.C	C source file from text of chapter 7.
	COPR.TXT	Example PROM copyright text file.
	HELLO.C	Demonstration program #1.
	MAKEFILE.1	NMAKE recipe for building HELLO.EXE.
	MAKEFILE.600	
	MAKEFILE.700	
	MAKEFILR.MVC	
	MODTEST.C	C source file from text of chapter 7.
	MODULE.BAT	PCM batch file from text of chapter 7.
	MODULE.H	C header file from text of chapter 7.
	MODV.C	C source file from text of chapter 7.
	OIT_DRVR.C	C source from text of chapter 6.
	RUNHELLO.BAT	PCM batch file for running HELLO.EXE.
	SEM.BAT	PCM batch file from text of chapter 7.
	SEM.H	C header file from text of chapter 7.
	SEM1.C	C source file from text of chapter 7.
	SEM2.C	C source file from text of chapter 7.
	SLICE.BAT	PCM batch file from text of chapter 7.
	SLICE.C	C source file from text of chapter 7.
	SWAP.BAT	PCM batch file from text of chapter 7.
	SWAP.C	C source file from text of chapter 7.
	T1.C	C source file from text of chapter 7.
	T2.C	C source file from text of chapter 7.
	TEST1.C	C source from text of chapter 8.
	TEST2.C	C source from text of chapter 8.
\PCMC\EXAMPLES \DEMO_3T	AAREADME	
	DATA.C	
	DEMO_3T.BAT	
	LOAD.BAT	
	MEMMODUL.H	
	MK_DEMO3	
	MK_DEMO3.600	
	MK_DEMO3.700	
	MK_DEMO3.MVC	
	PLC_30.PRT	
	PLC_70.PRT	
	TASK1.C	
	TASK2.C	
	TASK_AST.C	
\PCMC\EXAMPLES \DEMO_3T\PLC_30	CPUCFG.CFG	
	IOCFG.CFG	
	LMFOLDER.30	
	_MAIN.DEC	
	_MAIN.EXP	
	_MAIN.LH1	
	_MAIN.PRG	
	_MAIN.SYM	

Directory	File	Purpose
\PCMC\EXAMPLES \DEMO_3T\PLC_70	LMFOLDER.70 _MAIN.DAT _MAIN.DEC _MAIN.EXP _MAIN.LH1 _MAIN.PRG _MAIN.SYM	
\PCMC\INCLUDE	APITYPES.H CHKSUM.H CHKSUMNW.H CLRFLT.H CLRFLTNW.H CNTRL.H CNTRLNW.H CPU_DATA.H CTOS.H EXT.H FAULTS.H FAULTSNW.H MALLOC.H MEMORY.H MEMTYPES.H MIXTYPES.H MXREAD.H MXREADNW.H PCMCSARG.H PCMLIB.H PRGMEM.H PRGMEMNW.H SESSION.H STATUS.H STDARG.H STDIO.H STDLIB.H STRING.H SYSMEM.H SYSMEMNW.H TIME.H TIMENW.H UTILS.H UTILSNW.H VME.H VTOS.H	Data types used by PLC service request API. PLC API services for checking program and config integrity. NOWAIT versions of CHKSUM.H services. PLC API services for clearing I/O and PLC fault tables. NOWAIT versions of CLRFLT.H services. PLC API services for controlling PLC operation. NOWAIT versions of CNTRL.H services. Data types used by VTOS CPU: device. Replacement for MS-DOS include file with the same name. PLC API services for reading I/O and PLC fault tables. NOWAIT versions of FAULTS.H services. Replacement for MS-DOS include file with the same name. Replacement for MS-DOS include file with the same name. Data types used by SYSMEM.H services. Data types used by MXREAD.H services. PLC API services for reading collections of mixed PLC Data. NOWAIT versions of MXREAD.H services. No longer used – retained for compatibility. No longer used – retained for compatibility. PLC API services for reading and writing Series 90-70 %L and %P data. NOWAIT versions of PRGMEM.H services. Function prototypes for starting a PLC API session. Data Types used for reporting PLC operation status. Replacement for MS-DOS include file with the same name. Replacement for MS-DOS include file with the same name. Replacement for MS-DOS include file with the same name. Replacement for MS-DOS include file with the same name. PLC API services for reading and writing PLC data. NOWAIT versions of SYSMEM.H services. PLC API services for reading and setting PLC time-of-day clock. NOWAIT versions of time.H services. PLC API services for finding PLC CPU module type, memory sizes, etc. NOWAIT versions of UTILS.H services. New in this version Data types and function prototypes for VTOS services.

Directory	File	Purpose
\PCMC\LIB	APIL.LIB APIM.LIB APIS.LIB	PLC API libraries.
	CHKSTKL.OBJ CHKSTKM.OBJ CHKSTKS.OBJ CRT0LG.OBJ CRT0MD.OBJ CRT0SM.OBJ IFCALLMD.OBJ IFCALLRG.OBJ IFCALLSM.OBJ	Object files linked to PCM .EXE files.
	PCML.LIB PCMM.LIB PCMS.LIB	VTOS libraries.

Symbols

A

B

C

D

E

F

G

H

I

N

O

P

Q

R

S

T

U

V

W

X

Y