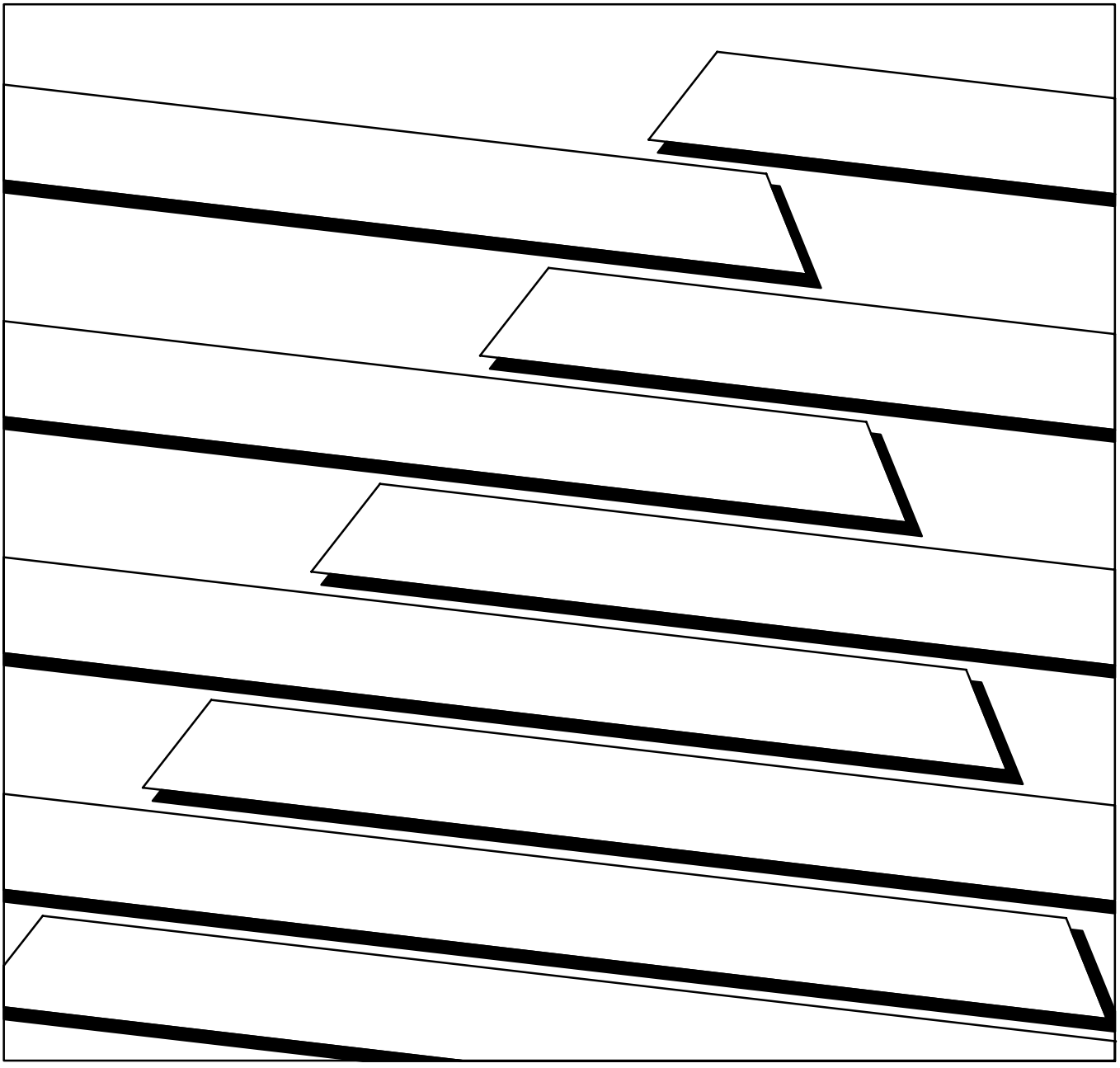
ALLEN-BRADLEY

OS-9 Technical

User Manual



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Introduction

Manual Organization

The OS-9® Technical User Manual is organized into two main sections: The OS-9 Technical Overview is covered in chapters 1 through 7 and Appendix A, B and C; OS-9 System Calls is covered in Appendix D.

The ***OS-9 Technical Overview*** contains the following chapters and appendices:

- **Chapter 1 – System Overview**
  Provides a general overview of OS-9's four levels of modularity, I/O processing, memory modules, and program modules.
- **Chapter 2 – The Kernel**
  Outlines the responsibilities of the kernel. Explains user and system state processing, memory management, system initialization, process creation and scheduling, and exception and interrupt processing.
- **Chapter 3 – OS-9 Input/Output System**
  Explains the software components of the OS-9 I/O system and the relationships between those components.
- **Chapter 4 – Interprocess Communications**
  Describes the five forms of interprocess communication supported by OS-9: signals, alarms, events, pipes, and data modules.
- **Chapter 5 – User Trap Handlers**
  Explains how to install and execute trap handlers, and provides an example of trap handler coding.
- **Chapter 6 – The Math Module**
  Discusses math module functions, and lists descriptions of the assembler calls you can use with the math module.
- **Chapter 7 – RBF File System**
  Explains OS-9's disk file organization, raw physical I/O on RBF devices, record locking, and file security.

- **Appendix A – Example Code**
  Contains example code that you can use as a guide when creating your own modules. Provides examples of RBF, SCF, and SBF device descriptors.

- **Appendix B – Path Descriptors and Device Descriptors**
  Includes the device descriptor initialization table definitions and path descriptor option tables for RBF, SCF, SBF, and PIPEMAN type devices.

- **Appendix C – OS-9 System Calls** contains descriptions for the following types of system calls:
  - *User-State System Calls*
  - *I/O System Calls*
  - *System-State System Calls*

The OS-9 Technical User Manual is designed for you to use in conjunction with the OS-9 Technical I/O User Manual.

System Overview

Chapter 1

The Kernel

Chapter 2

OS-9 Input/Output System

Chapter 3

Interprocess Communications

Chapter 4

User Trap Handlers

Chapter 5

The Math Module

Chapter 6

The Math Module

Chapter 6 Continued

OS-9 File System

Chapter 7

Example Code

Appendix A

Path Descriptors and Device Descriptors

Appendix B

OS-9 System Calls

Appendix C

Appendix C Continued

User-state System Calls Continued

OS-9 System Calls

Appendix C Continued

I/O System Calls

Appendix C Continued

Chapter 1

System Overview

System Modularity

OS-9® has four levels of modularity. These are described below and illustrated in Figure 1.1.

- **Level 1 – The Kernel, the Clock, and the Init Modules**
  The Kernel provides basic system services including Input/Output (I/O) management, process control, and resource management. The Clock module is a software handler for the specific real-time-clock hardware. The Init module is an initialization table the kernel uses during system startup.

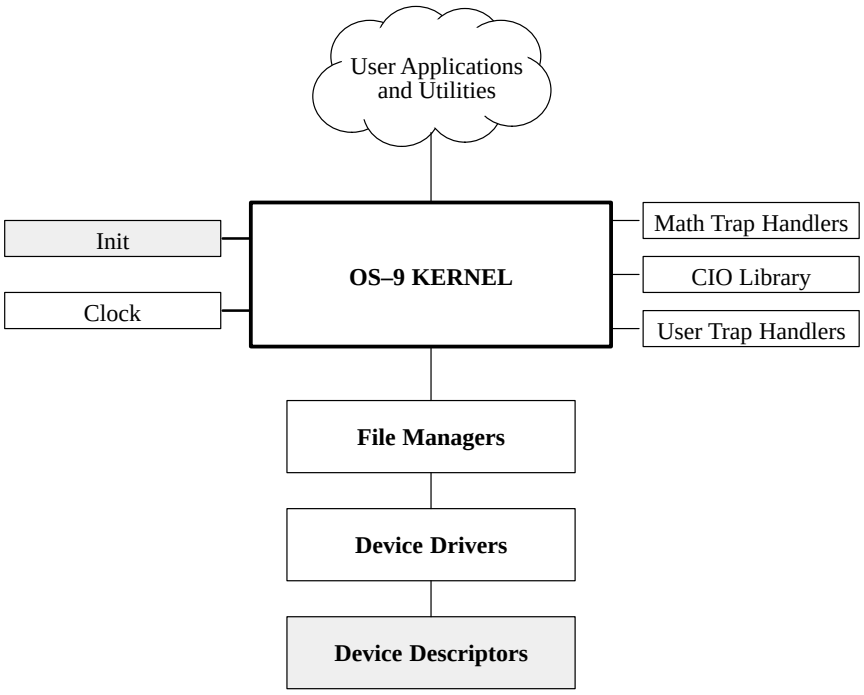
- **Level 2 – File Managers**
  File Managers process I/O requests for similar classes of I/O devices. Refer to the I/O Overview in this chapter for a list of the File Managers Microware currently supports.

- **Level 3 – Device Drivers**
  Device Drivers handle the basic physical I/O functions for specific I/O controllers. Standard OS-9 systems are typically supplied with a disk driver, serial port drivers for terminals and serial printers, and a driver for parallel printers. You can also add customized drivers of your own design or purchase drivers from a hardware vendor.

- **Level 4 – Device Descriptors**
  Device Descriptors are small tables that associate specific I/O ports with their logical name, device driver, and file manager. These modules also contain the physical address of the port and initialization data. By using device descriptors, only one copy of each driver is required for each specific type of I/O device, regardless of how many devices the system uses.

For specific information about file managers, device drivers, and device descriptors, refer to the I/O Overview (in this chapter), the OS-9 I/O System (Chapter 3), and the OS-9 Technical I/O Manual.

Figure 1.1
OS-9 Module Organization



Important: The shaded boxes contain non-executable code. These modules are referenced, not “called.” The kernel, file managers, and drivers reference descriptors directly, but only the kernel references the Init module directly.

An important component, the command interpreter (the Shell), is not shown in the above diagram. The Shell is an application program, not part of the operating system. It is described fully in Using Professional OS-9. To obtain a list of the specific modules that make up OS-9 for your system, use the Ident utility on the OS9Boot file.

Although all modules could be resident in ROM, the system bootstrap module is usually the only ROMed module in disk-based systems. All other modules are loaded into RAM during system startup.

I/O Overview

The kernel maintains the I/O system for OS-9. It provides the first level of I/O service by routing system call requests between processes, and the appropriate file managers and device drivers. Microware includes the following File Managers in the standard professional distribution:

File Manager:	Description:
RBF	The Random Block File Manager handles I/O for random-access, block-structured devices, such as floppy/hard disk systems.
SCF	The Sequential Character File Manager handles I/O for sequentially character-structured devices, such as terminals, printers, and modems.
SBF	The Sequential Block File Manager handles I/O for sequentially block-structured devices, such as tape systems.
PIPEMAN	The Pipe File Manager supports interprocess communications through memory buffers called *pipes*.

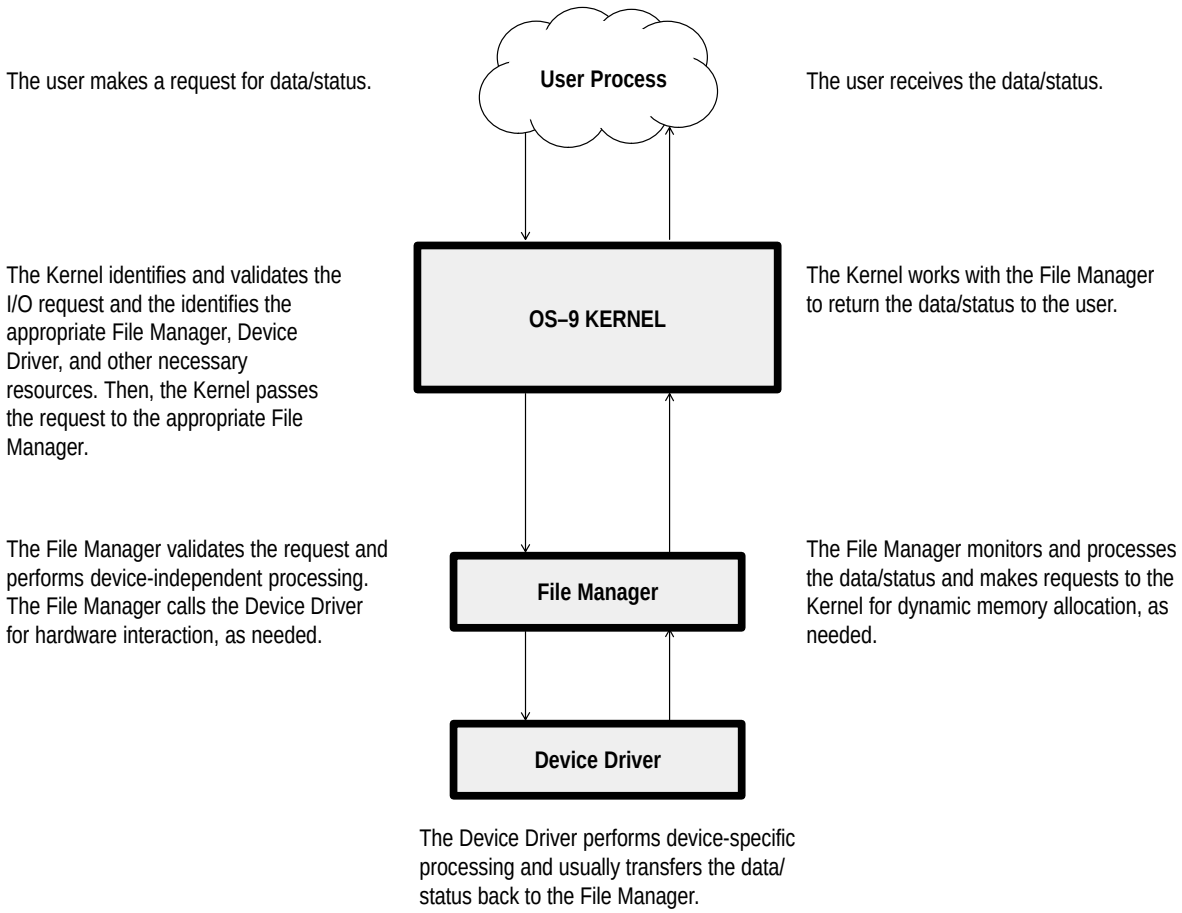
For specific information about the above file managers, refer to the OS-9 I/O System (Chapter 4) or the OS-9 Technical I/O Manual.

Microware also supports the following File Managers which are not included in the standard professional distribution:

File Manager:	Description:
PCF	PC File Manager handles reading/writing PC-DOS disks. It uses RBF drivers and is sold separately.
NFM	Network File Manager processes data requests over the OS-9 network. The OS-9/NFM package includes NFM.
ENPMAN	ENP10 Socket File Manager transfers requests to and from CMC ENP10 boards. OS-9/ESP, the Ethernet Support Package, includes NPMAN.
SOCKMAN	Socket File Manager creates and manages the interface to communication protocols (sockets). OS-9/ISP, the Internet Support Package, includes SOCKMAN.
IFMAN	Communications Interface File Manager manages network interfaces. OS-9/ISP, the Internet Support Package, includes IFMAN.
PKMAN	Pseudo-Keyboard File Manager provides an interface to the driver side of SCF to enable the software to emulate a terminal. OS-9/ESP and OS-9/ISP Packages include PKMAN.
GFM	The Graphics File Manager provides a full set of text and graphics primitives, input handling for keyboards and pointers, and high level features for handling user interaction in a real time, multi-tasking environment. The OS-9 RAVE package includes the Graphics File Manager.
UCM	The User Communications Manager handles video, pointer, and keyboard devices for CDI (Compact Disc Interactive). The CD-RTOS package includes UCM.
CDFM	The Compact Disc File Manager handles CD and audio devices, as well as access to CD ROM and CD audio. The CD-RTOS package includes CDFM.
NRF	The Non-Volatile RAM File Manager controls non-volatile RAM and handles a flat (non-hierarchical) directory structure. The CD-RTOS package includes NRF.

Figure 1.2 illustrates how OS-9 processes an I/O request:

Figure 1.2
Processing an OS-9 I/O Request



Memory Modules

OS-9 is unique in that it uses **memory modules** to manage both the physical assignment of memory to programs and the logical contents of memory. A memory module is a logical, self-contained program, program segment, or collection of data.

OS-9 supports ten pre-defined types of modules and allows you to define your own module types. Each type of module has a different function. Modules do not have to be complete programs or written in machine language. However, they must be **re-entrant**, **position-independent**, and conform to the basic module structure described in the next section.

The 68000 instruction set supports a programming style called **re-entrant** code, that is, code that does not modify itself. This allows two or more different processes to share one “copy” of a module simultaneously. The processes do not affect each other, provided that each process has an independent area for its variables.

Almost all OS-9 family software is re-entrant, and therefore uses memory very efficiently. For example, Scred requires 26K bytes of memory to load. If you make a request to run Scred while another user (process) is running it, OS-9 allows both processes to share the same copy, thus saving 26K of memory.

Important: Data modules are an exception to the re-entrant requirement. However, careful coordination is required for several processes to update a shared data module simultaneously.

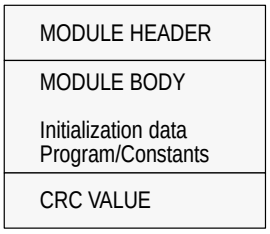
It does not matter where a **position-independent** module is loaded in memory. This allows OS-9 to load the program wherever memory space is available. In many operating systems, you must specify a **load address** to place the program in memory. OS-9 determines an appropriate load address for you when the program is run.

OS-9 compilers and interpreters automatically generate position-independent code. In assembly language programming, however, the programmer must insure position-independence by avoiding absolute address modes. Alternatives to absolute addressing are described in the OS-9/68000 Assembler/Linker/Debugger User’s Manual.

Basic Module Structure

Each module has three parts: a **module header**, a **module body**, and a **CRC value** (see Figure 1.3).

Figure 1.3
Basic Memory Module Format



The module header contains information that describes the module and its use. It is defined in assembly language by a psect directive. The linker creates the header at link-time. The information contained in the module header includes the module’s name, size, type, language, memory requirements, and entry point. For specific information about the structure and individual fields of the module header, refer to the list at the end of this chapter.

The module body contains initialization data, program instructions, constant tables, etc.

The last three bytes of the module hold a CRC value (Cyclic Redundancy Check value) to verify the module's integrity. The linker creates the CRC at link-time.

The CRC Value

The CRC (Cyclic Redundancy Check) is an error checking method used frequently in data communications and storage systems. It is also a vital part of the ROM memory module search technique. A CRC value is at the end of all modules to check the validity of the entire module. It provides an extremely reliable assurance that programs in memory are intact before execution, and is an effective backup for the error detection systems of disk drives, memory systems, etc.

OS-9 computes a 24-bit CRC value over the entire module, starting at the first byte of the module header and ending at the byte just before the CRC itself. OS-9 family compilers and linkers automatically generate the module header and CRC values. If required, your program can use the F$CRC system call to compute a CRC value over any specified databytes. Refer to F$CRC in the OS-9 System Calls manual for a full description of how F$CRC computes a module's CRC.

OS-9 does not recognize a module with an incorrect CRC value. Therefore, you must update the CRC value of any "patched" or modified module, or OS-9 cannot load the module from disk or find it in ROM. Use the OS-9 Fixmod utility to update the CRC's of patched modules.

ROMed Memory Modules

When a system reset starts OS-9, the kernel searches for modules in ROM. It detects them by looking for the module header sync code ($4AFC). When the kernel detects this byte pattern, it checks the header parity to verify a correct header. If this test succeeds, the kernel obtains the module size from the header and computes a 24-bit CRC over the entire module. If the computed CRC is valid, the module is entered into the module directory.

OS-9 links to all of its component modules found during the search. It automatically includes in the system module directory all ROMed modules present in the system at startup. This allows you to create systems that are partially or completely ROM-based. It also includes any non-system modules found in ROM. This allows location of user-supplied software during the start-up process, and its entry into the module directory.

Module Header Definitions

The following table and Figure 1.1 list definitions of the standard set of fields in the module header.

Name:	Description:
M$ID	**Sync bytes ($4AFC)** These constant bytes identify the start of a module.
M$SysRev	**System revision identification** Identifies the format of a module.
M$Size	**Size of module** The overall module size in bytes, including header and CRC.
M$Owner	**Owner ID** The group/user ID of the module's owner.
M$Name	**Offset to module name** The address of the module name string relative to the start (first sync byte) of the module. The name string can be located anywhere in the module and consists of a string of ASCII characters terminated by a null (zero) byte.
M$Accs	**Access permissions** Defines the permissible module access by its owner or other users. Module access permissions are divided into four sections: reserved (4 bits) public (4 bits) group (4 bits) owner (4 bits) Each of the non-reserved permission fields is defined as: bit 3 reserved bit 2 execute permission bit 1 write permission bit 0 read permission The total field is displayed as: -———ewr–ewr–ewr
M$Type	**Module Type Code** Module type values are in the oskdefs.d file. They describe the module type code as: Name: Description: 0 Not Used (Wild Card value in system calls) Prgm 1 Program Module Sbrtn 2 Subroutine Module Multi 3 Multi-Module (reserved for future use) Data 4 Data Module CSDData 5 Configuration Status Descriptor 6-10 Reserved for future use TrapLib 11 User Trap Library Systm 12 System Module (OS-9 component) Flmgr 13 File Manager Module Drivr 14 Physical Device Driver Devic 15 Device Descriptor Module 16-up User Definable

Name:	Description:
M$Lang	**Language** You can find module language codes in the oskdefs.d file. They describe whether the module is executable and which language the run-time system requires for execution (if any): Name: — Description: 0 — Unspecified Language (Wild Card value in system calls) Objct — 1 — 68000 machine language ICode — 2 — Basic I-code PCode — 3 — Pascal P-code CCode — 4 — C I-code (reserved for future use) CblCode — 5 — Cobol I-code FrtnCode — 6 — Fortran I-code — 7-15 — Reserved for future use 16-255 — User Definable NOTE: Not all combinations of module type codes and languages necessarily make sense.
M$Attr	**Attributes** Bit 5 - Module is a “system state” module. Bit 6 - Module is a ***sticky module***. A sticky module is retained in memory when its link count becomes zero. The module is removed from memory when its link count becomes –1 or memory is required for another use. Bit 7 - Module is re-entrant (sharable by multiple tasks).
M$Revs	**Revision level** The module’s revision level. If two modules with the same name and type are found in the memory search or loaded into memory, only the module with the highest revision level is kept. This enables easy substitution of modules for update or correction, especially ROMed modules.
M$Edit	**Edition** The software release level for maintenance. OS-9 does not use this field. Every time a program is revised (even for a small change), increase this number. We recommend that you key internal documentation within the source program to this system.
M$Usage	**Comments** Reserved for offset to module usage comments (not currently used).
M$Symbol	**Symbol table offset** Reserved for future use.
M$Parity	**Header parity check** The one’s complement of the exclusive-OR of the previous header “words.” OS9 uses this for a quick check of the module’s integrity.

Important: *Offset* refers to the location of a module field, relative to the starting address of the module. Resolve module offsets in assembly code by using the names shown here and linking the module with the relocatable library, sys.l or usr.l.

Figure 1.1
Module Header Standard Fields

Offset:	Name:	Usage:
$00	M$ID	Sync Bytes ($4AFC)
$02	M$SysRev	Revision ID
$04	M$Size	Module Size
$08	M$Owner	Owner ID
$0C	M$Name	Module Name Offset*
$10	M$Accs	Access Permissions
$12	M$Type	Module Type
$13	M$Lang	Module Language
$14	M$Attr	Attributes
$15	M$Revs	Revision Level
$16	M$Edit	Edit Edition
$18	M$Usage	Usage Comments Offset*
$1C	M$Symbol	Symbol Table
$20		Reserved
$2E	M$Parity	Header Parity Check
$30-up		Module Type Dependent
		Module Body
		CRC Check

* These fields are offset to strings.

Additional Header Fields For Individual Modules

Program, Trap Handler, Device Driver, File Manager, and System modules have additional standard header fields following the universal offsets. These additional fields are listed below and shown in Figure 1.2.

The **program module** is a common type of module (type: Prgm; language: Objct). A program module is executable as an independent process by the F$Fork or F$Chain system calls. The assembler and C compilers produce program modules, and most OS-9 commands are program modules. Program module headers have six fields in addition to the universal set.

Chapter 4 describes trap handler modules. The OS-9 Technical I/O Manual describes File Manager modules and Device Drivers modules.

Name:	Description:
(Program, Trap Handler, Device Driver, File Manager, and System Module Headers use the following two fields.)	
M$Exec	**Execution offset** The offset to the program's starting address. In the case of a file manager or driver, this is the offset to the module's entry table.
M$Excpt	**Default user trap execution entry point** The relative address of a routine to execute if an uninitialized user trap is called.
(Program, Trap Handler, and Device Driver Module Headers use the following field.)	
M$Mem	**Memory size** The required size of the program's data area (storage for program variables).
(Program and Trap Handler Module Headers use the following three fields.)	
M$Stack	**Stack size** The minimum required size of the program's stack area.
M$IData	**Initialized data offset** The offset to the initialization data area's starting address. This area contains values to copy to the program's data area. The linker places all constant values declared in vsects here. The first four-byte value is the offset from the beginning of the data area to which the initialized data is copied. The next four-byte value is the number of initialized data-bytes to follow.
M$IRefs	**Initialized references offset** The offset to a table of values to locate pointers in the data area. Initialized variables in the program's data area may contain values that are pointers to absolute addresses. Adjust code pointers by adding the absolute starting address of the object code area. Adjust the data pointers by adding the absolute starting address of the data area. The F$Fork system call does the effective address calculation at execution time using tables created in the module. The first word of each table is the most significant (MS) word of the offset to the pointer. The second word is a count of the number of least significant (LS) word offsets to adjust. F$Fork makes the adjustment by combining the MS word with each LS word entry. This offset locates the pointer in the data area. The pointer is adjusted by adding the absolute starting address of the object code or the data area (for code pointers or data pointers respectively). It is possible after exhausting this first count that another MS word and LS word are given. This continues until a MS word of zero and a LS word of zero are found.
(Trap Handler Module Headers use the following two fields.)	
M$Init	**Initialization execution offset** The offset to the trap initialization entry point.
M$Term	**Termination execution offset** The offset to the trap termination entry point. This offset is reserved by Microware for future use.

Important: Offset refers to the location of a module field, relative to the starting address of the module. Resolve module offsets in assembly code by using the names shown here and linking the module with the relocatable library: sys.l or usr.l.

Figure 1.2
Additional Header Fields for Individual Modules

Module type:	Offset:	Usage:
File Manager/System	$30	Execution Offset
	$34	Default User Trap Execution Entry Point
Device Driver	$38	Memory Size
	$3C	Stack Size
	$40	Initialized Data Offset
Program	$44	Initialized Reference Offset
Trap Handlers	$48	Initialization Execution Offset
	$4C	Termination Execution Offset

Chapter 2

The Kernel

Responsibilities of the Kernel

The **kernel** is the nucleus of OS-9. It manages resources, controls processing, and supervises Input/Output. It is a ROMable, compact OS-9 module.

The kernel's primary responsibility is to process and coordinate system calls, or service requests. OS-9 has two general types of system calls:

- calls that perform Input/Output, such as reads and writes
- calls that perform system functions. System functions include memory management, system initialization, process creation and scheduling, and exception/interrupt processing

When a system call is made, a user trap to the kernel occurs. The kernel determines what type of system call the user wants to perform. It directly executes the calls that perform system functions, but does not execute I/O calls. The kernel provides the first level of processing for each I/O call, then completes the function as required by calling the appropriate file manager or driver.

For information on specific system calls, refer to the OS-9 System Calls section of this manual.

For specific information about creating new file managers, and examples which you can adapt to your specific system needs, refer to the OS-9 Technical I/O Manual.

System Call Overview

For information about specific system calls, refer to OS-9 System Calls.

User-state and System-state

To understand OS-9's system calls, you should be familiar with the two distinct OS-9 environments in which object code can be executed:

Environment:	Description:
User-state	The normal program environment in which processes execute. Generally, user-state processes do not deal directly with the specific hardware configuration of the system.
System-state	The environment in which OS-9 system calls and interrupt service routines execute. On 68000-family processors, this is synonymous with supervisor state. System-state routines often deal with physical hardware present on a system.

Functions executing in system state have distinct advantages over those running in user state, including the following:

- A system-state routine has access to all of the processor's capabilities. For example, on memory protected systems, a system-state routine may access any memory location in the system. It may mask interrupts, alter OS-9 internal data structures, or take direct control of hardware interrupt vectors.
- Some OS-9 system calls are only accessible from system state.
- System-state routines are never time-sliced. Once a process enters system state, no other process executes until the system-state process finishes or goes to sleep (F$Sleep waiting for I/O). The only processing that may preempt a system-state routine is interrupt servicing.

System-state characteristics make it the only way to provide certain types of programming functions. For example, it is almost impossible to provide direct I/O to a physical device from user state. Not all programs, however, should run in system state. Reasons to use user-state processing rather than system-state processing include:

- User-state routines are time-sliced. In a multi-user environment, it is important to ensure that each user receives a fair share of the CPU time.
- Memory protection prevents user-state routines from accidentally damaging data structures they do not own.
- A user-state process can be aborted. If a system-state routine loses control, the entire system usually crashes.
- System-state routines are far more difficult and dangerous to debug than userstate routines. You can use the user-state debugger to find most user-state problems. Generally, system-state problems are much more difficult to find.
- User-state programs are essentially isolated from physical hardware. Because they are not concerned with I/O details, they are easier to write and port.

Installing System-state Routines

System-state routines have direct access to all system hardware, and have the power to take over the entire machine, crashing or hanging up the system. To help prevent this, OS9 limits the methods of creating routines that operate in system state.

There are four ways to provide system-state routines:

- Install an OS9P2 module in the system bootstrap file or in ROM. During cold start, the OS-9 kernel links to this module, and if found, calls its execution entry point. The most likely thing for such a module to do is install new system call codes. The drawback to this method is that the OS9P2 module must be in ROM or in the bootfile when the system is bootstrapped.

- Use the I/O system as an entry into system state. File managers and device drivers always execute in system state. The most obvious reason to write systemstate routines is to provide support for new hardware devices. It is possible to write a dummy device driver and use the I$GetStt or I$SetStt routines to provide a gateway to the driver.

- Write a trap handler module that executes in system state. For routines of limited use that are dynamically loaded and unlinked, this may be the most convenient method. In many cases, it is practical to debug most of the trap handler routines in user state, then convert the trap module to system state. To make a trap handler execute in system state, you must set the supervisor state bit in the module attribute byte and create the module as super user. When the user trap executes, it is in system state.

- A program executes in system state if the supervisor state bit in the module's attribute word is set and the module is owned by the super user. This can be useful in rare instances.

Important: System-state routines are not time-sliced, therefore they should be as short and fast as possible.

Kernel System Call Processing

All OS-9 system calls (service requests) are processed through the kernel. The system-wide relocatable library files, sys.l and usr.l, define symbolic names for all system calls. The files are linked with hand-written assembly language or compiler-generated code. The OS-9 Assembler has a built-in macro to generate system calls:

```
OS9     I$Read
```

This is recognized and assembled to produce the same code as:

```
TRAP    #0
dc.w    I$Read
```

In addition, the C Compiler standard library includes functions to access nearly all user mode OS-9 system calls from C programs.

Parameters for system calls are usually passed and returned in registers. There are two general types of system calls: system function calls (calls that do not perform I/O) and I/O calls.

System Function Calls
There are two types of system function calls, user-state and system-state:

Type:	Description:
User-state System Calls	These requests perform memory management, multi-tasking, and other functions for user programs. They are mainly processed by the kernel.
System-state System Calls	Only system software in system state can use these calls, and they usually operate on internal OS-9 data structures. To preserve OS-9's modularity, these requests are system calls rather than subroutines. User-state programs cannot access them, but system modules such as device drivers may use them.

The symbolic name of each system function call begins with F$. For example, the system call to link a module is F$Link.

In general, system-state routines may use any of the user-state system calls. However, you must avoid making system calls at inappropriate times. For example, avoid I/O calls, timed sleep requests, and other calls that can be particularly time consuming (such as F$CRC) in an interrupt service routine.

Memory requested in system state is *not* recorded in the process descriptor memory list. Therefore, you must ensure that the memory is returned to the system before the process terminates.

ATTENTION: Avoid the F$TLink and F$Icpt system calls in system-state routines. Certain portions of the C library may be inappropriate for use in system state.

I/O Calls

I/O calls perform various I/O functions. The file manager, device driver, and kernel process I/O calls for a particular device. The symbolic names for this category of calls begin with I$. For example, the read service request is I$Read.

You may use any I/O system call in a system-state routine, with one slight difference than when executed in user-state. All path numbers used in system state are *system* path numbers. Each process descriptor has a path number that converts process local path numbers into system path numbers. The system itself has a global path number table to convert system path numbers into actual addresses of path descriptors. You must make system-state I/O system calls using system path numbers.

For example, the OS-9 F$PErr system call prints an error message on the caller's standard error path. To do this, it may not simply perform output on path number two. Instead it must examine the caller's process descriptor and extract the system path number from the third entry (0, 1, 2, ...) in the caller's path table.

When a user-state process exits with I/O paths open, the F$Exit routine automatically closes the paths. This is possible because OS-9 keeps track of the open paths in the process's path table. In system state, the I$Open and I$Create system calls return a system path number which is not recorded in the process path table or anywhere else by OS-9. Therefore, the system-state routine that opens any I/O paths must ensure that the paths are eventually closed, even if the underlying process is abnormally terminated.

Memory Management

To load any object (such as a program or constant table) into memory, the object *must* have the standard OS-9 memory module format as described in Chapter 1. This enables OS-9 to maintain a **module directory** to keep track of modules in memory. The module directory contains the name, address, and other related information about each module in memory.

OS-9 adds the module to the module directory when it is loaded into memory. Each directory entry contains a **link count**. The link count is the number of processes using the module.

When a process links to a module in memory, the module's link count increments by one. When a process unlinks from a module, the module's link count decrements by one. When a module's link count becomes zero, its memory is de-allocated and it is removed from the module directory, unless the module is **sticky**.

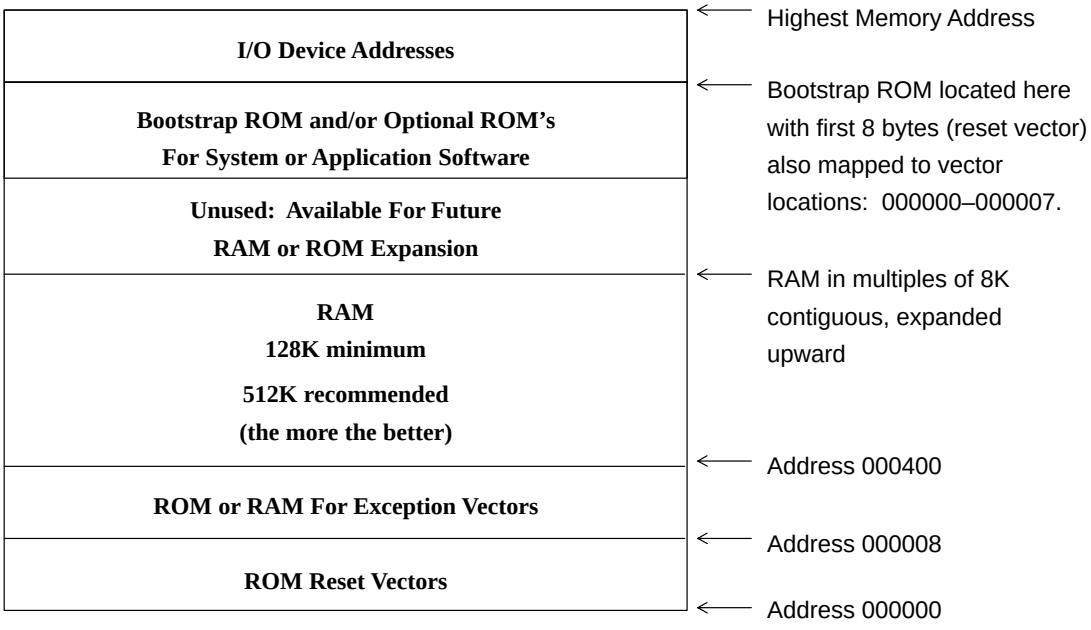
A **sticky module** is not removed from memory until its link count becomes –1 or memory is required for another use. A module is sticky if the sixth bit of the module header's attribute field (M$Attr) is set.

OS-9 Memory Map

OS-9 uses a software memory management system that contains all memory within a single memory map. Therefore, all user tasks share a common address space.

A map of a typical OS-9 memory space is shown in Figure 2.1. Unless otherwise noted, the sections shown need not be located at specific addresses. However, Microware recommends that you keep each section in contiguous reserved blocks, arranged in an order that facilitates future expansion. Whenever possible, it is best to have physically contiguous RAM.

Figure 2.1
Typical OS-9 Memory Map



Important: For the 68020, 68030, 68040, and CPU32 family of CPUs, you can set the Vector Base Register (VBR) anywhere in the system. Thus, for these types of systems, there is no requirement that RAM or ROM be at address 0.

System Memory Allocation

During the OS-9 start-up sequence, an automatic search function in the kernel and the boot ROM finds blocks of RAM and ROM. OS-9 reserves some RAM for its own data structures. ROM blocks are searched for valid OS-9 ROM modules.

OS-9 requires a variable amount of memory. Actual requirements depend on the system configuration and the number of active tasks and open files. The following sections describe approximate amounts of memory used by various parts of OS-9.

Operating System Object Code
A complete set of typical operating system component modules (kernel, file managers, device drivers, device descriptors, tick driver) occupies about 50K to 64K bytes of memory. On disk-based systems, these modules are normally bootstrap-loaded into RAM. OS-9 does not dynamically load overlays or swap system code; therefore, no additional RAM is required for system code.

You can place OS-9 in ROM for non-disk systems. The typical operating system object code for ROM-based, non-disk systems occupies about 30K to 40K bytes.

System Global Memory
OS-9 uses a minimum of 8K RAM for internal use. The system global memory area is usually located at the lowest RAM addressed. It contains an exception jump table, the debugger/boot variables, and a system global area. Variables in the system global area are symbolically defined in the sys.l library and the variable names begin with D_. The Reset SSP vector points to the system global area.

ATTENTION: User programs should *never* directly access system global variables because of issues such as portability and (depending on hardware) memory protection. System calls are provided to allow user programs to read the information in this area.

System Dynamic Memory
OS-9 maintains dynamic-sized data structures (such as I/O buffers, path descriptors, process descriptors, etc.) which are allocated from the general RAM area when needed. The System Global Memory area keeps pointers to the addresses of these data structures. A typical small system uses approximately 16K of RAM. The total depends on elements such as the number of active devices, the memory, and the number of active processes. The sys.l library source files include the exact sizes of all the system’s data structure elements.

Free Memory Pool
All unused RAM memory is assigned to a free memory pool. Memory space is removed and returned to the pool as it is allocated or de-allocated for various purposes. OS-9 automatically assigns memory from the free memory pool whenever any of the following occur:

- Modules are loaded into RAM.
- New processes are created.
- Processes request additional RAM.
- OS-9 requires more I/O buffers or its internal data structures must be expanded.

Storage for user program object code modules and data space is dynamically allocated from and de-allocated to the free memory pool. User object code modules are automatically shared if two or more tasks execute the same object program. User object code application programs can also be stored in ROM memory.

The total memory required for user memory depends largely on the application software to be run. Microware suggests that you have a system minimum of 128K plus an additional 64K per user available. Alternatively, small ROM-based control system might only need 32K of memory.

Memory Fragmentation

Once a program is loaded, it must remain at the address where it was originally loaded. Although position-independent programs can be initially placed at any address where free memory is available, program modules cannot be relocated dynamically after they are loaded. This can lead to **memory fragmentation**.

When programs are loaded, they are assigned the first sufficiently large block of memory at the highest address possible in the address space. (If a colored memory request is made, this may not be true. Refer to the following section for more information on colored memory.) If a number of program modules are loaded, and subsequently one or more non-contiguous modules are unlinked, several fragments of free memory space exist. The total free memory space may be quite large. However, because it is scattered, not enough space will exist in a single block to load a particular program module.

You can avoid memory fragmentation by loading modules at system startup. This places the modules in contiguous memory space. Or, you can initialize each standard device when booting the system. This allows the devices to allocate memory from higher RAM than would be available if the devices were initialized after booting.

If serious memory fragmentation does occur, the system administrator can kill processes and unlink modules in ascending order of importance until there is sufficient contiguous memory to proceed. Use the mfree utility to determine the number and size of free memory blocks.

Colored Memory

OS-9 colored memory allows a system to recognize different memory types and reserve areas for special purposes. For example, you could design a part of a system's RAM to store video images and battery back up another part. The kernel allows isolation and specific access of areas of RAM like these. You can request specific memory types or "colors" when allocating memory buffers, creating modules in memory, or loading modules into memory. If a specific type of memory is not available, the kernel returns error #237, E$NoRAM.

Colored memory lists are not essential on systems with RAM consisting of one homogeneous type, although they can improve system performance on some systems and allow greater flexibility in configuring memory search areas. The default memory allocation requests are still appropriate for most homogeneous systems and for applications which do not require one memory type over another. Colored memory lists are required for the F$Trans system call to perform address translation.

Colored Memory Definition List
The kernel must have a description of the CPU's address space to make use of the colored memory routines. You can establish colored memory by including a colored memory definition list (MemList) in the systype.d file, which then becomes part of the Init module. The list describes each memory region's characteristics. The kernel searches each region in the list for RAM during system startup.

A colored memory definition list contains the following information:

- memory color (type)
- memory priority
- memory access permissions
- local bus address
- block size the kernel's coldstart routine uses to search the area for RAM or ROM
- external bus translation address (for DMA, dual-ported RAM, etc.)
- optional name

The memory list may contain as many regions as needed. If no list is specified, the kernel automatically creates one region that describes the memory found by the bootstrap ROM.

MemList is a series of MemType macros defined in systype.d and used by init.a. Each line in the MemList must contain all the following parameters, in order:

```
type, priority, attributes, blksiz, addr begin, addr end, name, DMA-offset
```

The colored memory list must end with a longword of zero. The following describes the MemList parameters:

Parameter:	Size:	Size:
Memory Type	word	Type of memory. Three memory types are currently defined in memory.h: SYSRAM 0x01 System RAM memory VIDEO1 0x80 Video memory for plane A VIDEO2 0x81 Video memory for plane B
Priority	word	Priority of memory (0-255). High priority memory is allocated first. If the block priority is 0, then the block can only be allocated by a request for the specific color (type) of the block.
Access permissions	word	Memory type access bit definitions: bit 0 B_USER User processes can allocate this memory. NOTE: This bit is ignored if the B_ROM bit is set. bit 1 B_PARITY Parity memory; the kernel initializes this memory during startup. NOTE: Only B_USER memory may be initialized. bit 2 B_ROM ROM; the kernel searches this memory for modules during startup. NOTE: B_ROM memory *cannot* be allocated by processes, as the B_USER and B_PARITY bits are ignored if B_ROM is set.
Search Block Size	word	The kernel checks every search block size to see if RAM/ROM exists.
Low Memory Limit	long	Beginning address of the block, as referenced by the CPU.
High Memory Limit	long	End address of the block, as referenced by the CPU.
Description String Offset	word	Offset of a user-defined string that describes the type of memory block.
Address Translation Adjustment	long	The external bus address of the beginning of the block. If zero, this field does not apply. Refer to F$Trans for more information.

The following is an example system memory map:

CPU address:	Bus address:	Memory size:	Physical location:
$00000000	$00200000	$200000	on-board cpu ram
$00600000	$00600000	$200000	VMEbus ram

A corresponding MemList table might appear as follows:

```
* memory list definitions for init module (user adjustable)
 align
* MemType  type, prior, attributes, blksiz, addr limits, name, DMA–offset
MemList
* on–board ram covered by “rom memory list:”
*  – this memory block is known to the “rom’s memory list,” thus it was
*    “parity initialized” by the rom code.
*  – the cpu’s local base address of the block is at $00000000.
*  – the bus base address of the block is at $200000.
*  – this ram is fastest access for the cpu, so it has the highest priority.
*
 MemType SYSRAM,255,B_USER,4096,0,$200000,OnBoard,$200000

* off–board expansion ram
*  – this memory block is not known to the “rom’s memory list,”
*    thus it needs “parity initialization” by the kernel.
*  – as the block is accessed over the bus, the base address of the block
*    is the same for cpu and dma accesses.
*  – this ram is slower access than on–board ram, therefore it
*    has a lower priority than the on–board ram.
*
 MemType SYSRAM,250,B_USER+B_PARITY,4096,$600000,$800000,OffBoard,0
 dc.l 0 end of list

OnBoard dc.b “fast on–board RAM”,0
OffBoard dc.b “VMEbus memory”,0
```

Colored Memory in Homogenous Memory Systems

Colored memory definitions are not essential for homogenous memory systems. However, colored memory definitions in this type of system can improve system performance and simplify memory list re-configuration.

System Performance

In a homogeneous memory system, the kernel allocates memory from the top of available RAM when requests are made by F$SRqMem (for example, when loading modules). If the system has RAM on-board the CPU and off-board in external memory boards, the modules tend to be loaded into the off-board RAM, because OS-9 always uses high memory first. On-board RAM is not used for a F$SRqMem call until the off-board memory is unable to accommodate the request.

Programs running in off-board memory execute slower than those running in on-board memory, due to bus access arbitration. Also, external bus activity increases. This may impact the performance of other bus masters in the system.

The colored memory lists can be used to reverse this tendency in the kernel, so that a CPU does not use off-board memory until all of its on-board memory is utilized. This results in faster program execution and less saturation of the system's external bus. Do this by making the priority of the on-board memory higher than off-board memory, as shown in the example lists on the preceding page.

Re-configuring Memory Areas
In a homogeneous memory system, the memory search areas are defined in the ROM's Memory List. If you do not use colored memory, you must make new ROMs from source code (usually impossible for end-users) or from a patched version of the original ROMs (usually difficult for end-users) to make changes to the memory search areas.

The colored memory lists simplify changes by configuring the search areas as follows:

- The ROM's memory list describes only the on-board memory.
- The colored memory lists in systype.d define the on-board memory and any external bus memory search areas in the Init module only.

The use of colored memory in a homogeneous memory system allows you to easily reconfigure the external bus search areas by adjusting the lists in systype.d and making a new Init module. The ROM does not require patching.

System Initialization

After a hardware reset, the bootstrap ROM executes the kernel (which is located in ROM or loaded from disk, depending on the system involved). The kernel initializes the system, which includes locating ROM modules and running the system startup task (usually Sysgo).

Init: The Configuration Module

Init is a non-executable module of type `Systm` (code $0C) which contains a table of system startup parameters. During startup, Init specifies initial table sizes and system device names, but it is always available to determine system limits. It must be in memory when the kernel executes and usually resides in the OS9Boot file or in ROM.

The Init module begins with a standard module header (Chapter 1, Figure 1-4) and the additional fields shown in the following table and in Table 2.A.

Important: Refer to Appendix A for an example program listing of the Init module. Offset names are defined in the relocatable library sys.l.

Name:	Description:
M$PollSz	**IRQ polling size** The number of entries in the IRQ polling table. Each interrupt generating device control register requires one entry. The IRQ polling table has 32 entries by default. Each table entry is 18 bytes long.
M$DevCnt	**Device table size** The number of entries in the system device table. Each device on the system requires one entry in this table.
M$Procs	**Initial process table size** The initial number of active processes allowed in the system. If this table gets full, it automatically expands as needed.
M$Paths	**Initial path table size** The initial number of open paths in the system. If this table gets full, it automatically expand as needed.
M$SParam	**Offset to parameter string for startup module** The offset to the parameter string (if any) to pass to the first executable module.
M$SysGo	**First executable module name offset** The offset to the name string of the first executable module, usually Sysgo or Shell.
M$SysDev	**Default directory name offset** The offset to the initial default directory name string, usually /d0 or /h0. The kernel does a chd and chx to this device prior to forking the initial device. If the system does not use disks, this offset must be zero.
M$Consol	**Initial I/O pathlist name offset** The offset to the initial I/O pathlist string, usually /term. This pathlist is opened as the standard I/O path for the initial process. It is generally used to set up the initial I/O paths to and from a terminal. This offset should contain zero if no console device is in use.
M$Extens	**Customization module name offset** The offset to the name string of a list of customization modules (if any). A customization module complements or changes the existing OS-9 standard system calls. These modules are searched for at startup; they are usually found in the bootfile. If found, they execute in system state. Module names in the name string are separated by spaces. The default name string to search for is OS9P2. If there are no customization modules, set this value to zero. NOTE: A customization module may only alter the d0, d1, and ccr registers. NOTE: Customization modules must be system-type modules.
M$Clock	**Clock module name offset** The offset to the clock module name string. If there is no clock module name string, set this value to zero.
M$Slice	**Time-slice** The number of clock ticks per time-slice. If M$Slice is not specified, it defaults to 2.
M$Site	**Offset to installation site code** This value is usually set to zero. OS-9 does not currently use this field.

Name:	Description:
M$Instal	**Offset to installation name** The offset to the installation name string.
M$CPUTyp	**CPU Type** CPU type: 68000, 68008, 68010, 68020, 68030, 68040, 68070, 683xx.
M$OS9Lvl	**Level, version, and edition** This four byte field is divided into three parts: level: 1 byte version: 2 bytes edition: 1 byte For example, level 2, version 2.4, edition 0 would be 2240.
M$OS9Rev	**Revision offset** The offset to the OS-9 level/revision string.
M$SysPri	**Priority** The system priority at which the first module (usually Sysgo or Shell) executes. This is generally the base priority at which all processes start.
M$MinPty	**Minimum priority** The initial system minimum executable priority. For specific information on minimum priority, see the Process Execution section later in this chapter and F$SetSys in Chapter 1 of OS-9 System Calls.
M$MaxAge	**Maximum age** The initial system maximum natural age. For specific information on maximum age, see the Process Execution section later in this chapter and F$SetSys in Chapter 1 of OS-9 System Calls.
M$Events	**Number of entries in the events table** The initial number of entries allowed in the events table. If the table gets full, it automatically expands as needed. See the Events section of Chapter 3 for more specific information.
M$Compat	**Revision compatibility** This byte is used for revision compatibility. The following bits are currently defined: Bit# Function 0 Set to save all registers for IRQ routines 1 Set to prevent the kernel from using stop instructions 2 Set to ignore sticky bit in module headers 3 Set to disable cache burst operation (68030 systems) 4 Set to patternize memory when allocated or de-allocated 5 Set to prevent kernel cold-start from starting system clock
M$Compat2	**Revision compatibility #2** This byte is used for revision compatibility. The following bits are currently defined: Bit# Function 0 0 External instruction cache is *not* snoopy* 1 External instruction cache is snoopy or absent 1 0 External data cache is *not* snoopy 1 External data cache is snoopy or absent 2 0 On-chip instruction cache is *not* snoopy 1 On-chip instruction cache is snoopy or absent 3 0 On-chip data cache is *not* snoopy 1 On-chip data cache is snoopy or absent 7 0 Kernel disables data caches when in I/O 1 Kernel *does not* disable data caches when in I/O * snoopy = cache that maintains its integrity without software intervention.

Name:	Description:
M$MemList	**Colored memory list** An offset to the memory segment list. The colored memory list contains an entry for each type of memory in the system. It is terminated by a long word of zero. See F$SRqCMem for further information. Each entry in the list has the following format: Offset Description $00 Memory Type; SYSRAM = System RAM VIDEO1 = Plane A Video VIDEO2 = Plane B Video $02 Priority $04 Access permissions: B_USER = User processes allocate memory. B_PARITY = Parity memory; kernel initializes it during startup. B_ROM = kernel searches this for modules during startup. $06 Search block size $08 Low memory limit $10 Offset to description string $12 Reserved (must be zero) $14 Address translation adjustment $18 Reserved (must be zero) $1C Reserved (must be zero)
M$IRQStk	**Kernel's IRQ stack size** The size (in LONGWORDS) of the kernel's IRQ stack. The value of this field must be 0, or >= 256 and <=$ffff. If zero, the kernel uses a small default IRQ stack (not recommended).
M$ColdTrys	**Retry counter** This is the retry counter if the kernel's initial chd (to the default system device) fails.

Important: Offset refers to the location of a module field, relative to the starting address of the module. Module offsets are resolved in assembly code by using the names shown here and linking the module with the relocatable library: sys.l or usr.l.

Table 2.A
Additional Fields for the Init Module

Offset:	Name:	Description:
$30	Reserved	Currently reserved for future use.
$34	M$PollSz	Number of IRQ polling table entries.
$36	M$DevCnt	Device table size.
$38	M$Procs	Initial process table size.
$3A	M$Paths	Initial path table size.
$3C	M$SParam	Parameter string for startup module (usually Sysgo).
$3E	M$SysGo	Offset to name string of first executable module.
$40	M$SysDev	Offset to the initial default directory name string.
$42	M$Consol	Offset to the initial I/O pathlist string.
$44	M$Extens	Offset to a name string of customization modules.
$46	M$Clock	Offset to the clock module name string.
$48	M$Slice	Number of clock ticks per time-slice.
$4A	Reserved	Currently reserved for future use.
$4C	M$Site	Offset to the installation site code.
$50	M$Instal	Offset to the installation name string.
$52	M$CPUTyp	CPU type.
$56	M$OS9Lvl	Level, version, and edition number of the operating system.
$5A	M$OS9Rev	Offset to the OS-9 level/revision string.
$5C	M$SysPri	Initial system priority.
$5E	M$MinPty	Initial system minimum executable priority.
$60	M$MaxAge	Initial system maximum natural age.
$62	Reserved	Currently reserved for future use.
$66	M$Events	Initial number of entries allowed in the events table.
$68	M$Compat	Compatibility flag one. Byte is used for revision compatibility.
$69	M$Compat2	Compatibility flag two. Byte is used for revision compatibility.
$6A	M$MemList	Offset to the memory segment list.
$6C	M$IRQStk	Size of the kernel's IRQ stack.
$6E	M$ColdTrys	Retry counter if the kernel's initial chd fails.

Important: The strings themselves follow the 28 byte reserved section.

Sysgo

Sysgo is the first user process started after the system startup sequence. Its standard I/O is on the system console device.

Sysgo usually executes as follows:

1. Changes to the CMDS execution directory on the system device.
2. Executes the startup file (as a script) from the root of the system device.
3. Forks a shell on the system console.
4. Waits for that shell to terminate and then forks it again. Therefore, there is always a shell running on the system console, unless Sysgo dies.

You cannot use the standard Sysgo module for disk systems on non-disk systems, but it is easy to customize.

You may eliminate Sysgo by specifying shell as the initial startup module and specifying a parameter string similar to:

```
startup; ex tsmon /term
```

See Appendix A for an example source listing of the Sysgo module.

Customization Modules

Customization modules are additional modules you can execute at boot time to enhance OS-9's capabilities. They provide a convenient way to install a new system call code or collection of system call codes, for example, a system security module. The kernel calls the modules at boot time if their names are specified in the extension list of the Init module and the kernel can locate them.

Important: Customization modules may only modify the d0, d1, and ccr registers.

To include a customization module in the system, you can either burn the module into ROM or complete the following steps:

1. Assemble/link the module so that the final object code appears in the /h0/CMDS/BOOTOBJS directory.

2. Create a new Init module:

Change to the DEFS directory and edit the CONFIG macro in the systype.d file. The name of the new module must appear in the Init module extension list. For example, if the name of the new module is mine, add the following line immediately before the endm line:

```
Extens dc.b “os9p2 mine”,0
```

Important: `os9p2` is the name of the default customization module.

Remake the Init module.

3. Create a new bootfile:

Change to the /h0/CMDS/BOOTOBJS directory and edit the bootlist file so that the customization module name appears in the list.

Create a new bootfile with the os9gen utility. For example:

```
os9gen /h0fmt –z=bootlist
```

4. Reboot the system and make sure that the new module is operational.

Process Creation

All OS-9 programs run as **processes** or **tasks**. The F$Fork system call creates new processes. The name of the primary module that the new process is to execute initially is the most important parameter passed in the fork system call. The following outlines the creation process:

1. Locate or Load the Program.
OS-9 tries to find the module in memory. If it cannot find the module, it loads a mass-storage file into memory using the requested module name as a file name.

2. Allocate and Initialize a Process Descriptor.
After OS-9 locates the primary module, it assigns a data structure called a **process descriptor** to the new process. The process descriptor is a table that contains information about the process: its state, memory allocation, priority, I/O paths, etc. The process descriptor is automatically initialized and maintained. The process does not need to know about the descriptor’s existence or contents.

3. **Allocate the Stack and Data Areas.**
   The primary module's header contains a data and stack size. OS-9 allocates a **contiguous memory area** of the required size from the free memory space. The following section discusses process memory areas.

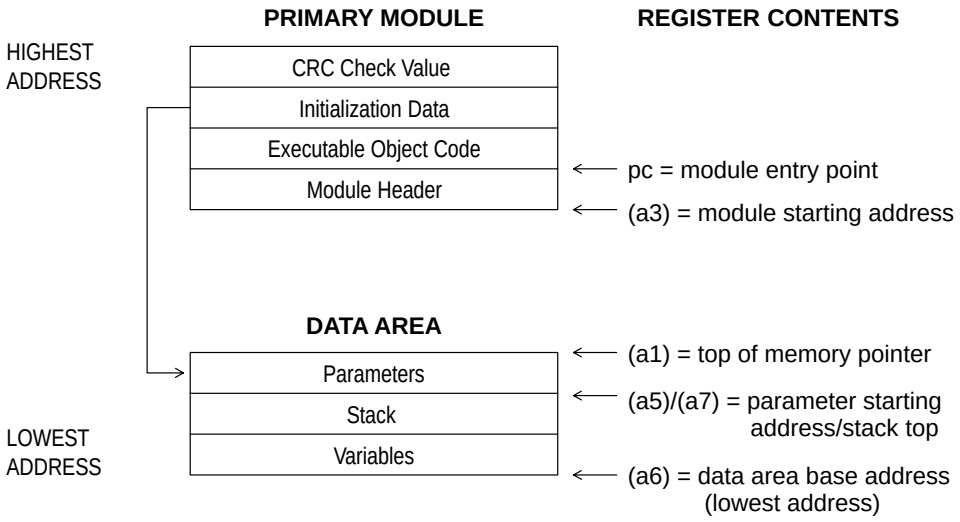
4. **Initialize the Process.**
   OS-9 sets the new process's registers to the proper addresses in the data area and object code module (see Figure 2.2). If the program uses initialized variables and/or pointers, they are copied from the object code area to the proper addresses in the data area.

If OS-9 cannot perform any of these steps, it aborts the creation of the new process and notifies the process that originated the fork of the error. If OS-9 completes all the steps, it adds the new process to the active process queue for execution scheduling.

The new process is also assigned a **process ID**. This is a unique number which is the process's identifier. Other processes can communicate with it by referring to its ID in system calls. The process also has an associated **group ID** and **user ID**. These identify all processes and files belonging to a particular user and group of users. The group and user ID's are inherited from the parent process.

Processes terminate when they execute an F$Exit system service request or when they receive fatal signals or errors. Terminating the process closes any open paths, de-allocates the process's memory, and unlinks its primary module.

Figure 2.2
New Process's Initial Memory Map and Register Contents



Registers passed to the new process:

sr	0000	(a0)	undefined
pc	module entry point	(a1)	top of memory pointer
d0.w	process ID	(a2)	undefined
d1.l	group/user ID	(a3)	primary module pointer
d2.w	priority	(a4)	undefined
d3.w	# of paths inherited	(a5)	parameter pointer
d4.l	undefined	(a6)	static storage (data area) base pointer
d5.l	parameter size	(a7)	stack pointer (same as a5)
d6.l	total initial memory allocation		
d7.l	undefined		

Important: `(a6)` is always biased by $8000 to allow object programs to access 64K of data using indexed addressing. You can usually ignore this bias because the OS-9 linker automatically adjusts for it.

Process Memory Areas

OS-9 divides all processes (programs) into two logically separate memory areas: code and data. This division provides OS-9's modular software capabilities.

Each process has a unique data area, but not necessarily a unique program memory module. This allows two or more processes to share the same copy of a program. This technique is an automatic function of OS-9 and results in extremely efficient use of available memory.

A program must be in the form of an executable memory module (described in Chapter 1) to be run. The program is position-independent and ROMable, and the memory it occupies is considered read-only. It may link to and execute code in other modules.

The process's data area is a separate memory space where all of the program's variables are kept. The top part of this area is used for the program's stack. The actual memory addresses assigned to the data area are unknown at the time the program is written. A base address is kept in a register (usually a6) to access the data area. You can read or write to this area.

If a program uses variables that require initialization, OS-9 copies the initial values from the read-only program area to the data area where the variables actually reside. The OS-9 linker builds appropriate initialization tables which initialize the variables.

Process States

A process is either in active, waiting, or sleeping state:

Process:	Description:
ACTIVE	The process is active and ready for execution. The scheduler gives active processes time for execution according to their relative priority with respect to all other active processes. It uses a method that compares the ages of all active processes in the queue. It gives some CPU time to all active processes, even if they have a very low relative priority.
WAITING	The process is inactive until a child process terminates or until a signal is received. The process enters the wait state when it executes a F$Wait system service request. It remains inactive until one of its descendant processes terminates or until it receives a signal.
SLEEPING	The process is inactive for a specified period of time or until it receives a signal. A process enters the sleep state when it executes an F$Sleep service request. F$Sleep specifies a time interval for which the process is to remain inactive. Processes often sleep to avoid wasting CPU time while waiting for some external event, such as the completion of I/O. Zero ticks specifies an infinite period of time. Processes waiting on an event are also included in the sleep queue.

There is a separate queue (linked list of process descriptors) for each process state. State changes are made by moving a process descriptor from its current queue to another queue.

Process Scheduling

OS-9 is a multi-tasking operating system, that is, two or more independent programs, called **processes** or **tasks**, can execute simultaneously. Several processes share each second of CPU time. Although the processes appear to run continuously, the CPU only executes one instruction at a time. The OS-9 kernel determines which process, and how long, to run based on the priorities of the active processes. **Task-switching** is the action of switching from the execution of one process to another. Task-switching does not affect the programs' execution.

A real-time clock interrupts the CPU at every **tick**. By default, a tick is .01 second (10 milliseconds). At any occurrence of a tick, OS-9 can suspend execution of one program and begin execution of another. The tick length is hardware dependent. Thus, to change the tick length, you must rewrite the clock driver and re-initialize the hardware.

A **slice** or **time-slice** is the longest amount of time a process will control the CPU before the kernel re-evaluates the active process queue. By default, a slice is two ticks. You can change the number of ticks per slice by adjusting the system global variable D_TSlice or by modifying the Init module.

To ensure efficiency, only processes on the active process queue are considered for execution. The active process queue is organized by **process age**, a count of how many task switches have occurred since the process entered the active queue plus the process's initial priority. The oldest process is at the head of the queue. OS-9's scheduling algorithm allocates some execution time to each active process.

When a process is placed in the active queue, its age is set to the process's assigned priority and the ages of all other processes increment. Ages never increment beyond $FFFF.

After the currently executing process's time-slice, the kernel executes the process with the highest age.

Pre-emptive Task-switching

During critical real-time applications you sometimes need fast interrupt response time. OS9 provides this by pre-empting the currently executing process when a process with a higher priority becomes active. The lower priority process loses the remainder of its time-slice and is re-inserted into the active queue.

Task-switching is affected by two system global variables: D_MinPty (minimum priority) and D_MaxAge (maximum age). Both variables are initially set in the Init module. Users with a group ID of zero (super users) can access both variables through the F$SetSys system call.

If a process's priority or age is less than D_MinPty, the process is not considered for execution and is not aged. Usually, this variable is not used; it is set to zero.

ATTENTION: If the minimum system priority is set above the priority of all running tasks, the system is completely shut down. You must reset to recover. Therefore, it is crucial to restore D_MinPty to a normal level when the critical task(s) finishes.

D_MaxAge is the maximum age to which a process can increment. When D_MaxAge is activated, tasks are divided into two classes, high priority and low priority:

- High priority tasks receive all of the available CPU time and do not age.
- Low priority tasks do not age past D_MaxAge. Low priority tasks are run only when the high priority tasks are inactive. Usually, this variable is not used; it is set to zero.

Important: A system-state process is *not* pre-empted until it finishes, unless it voluntarily gives up its time-slice. This exception is made because system-state processes may be executing critical routines that affect shared system resources which may block other unrelated processes.

Exception and Interrupt Processing

One of OS-9's features is its extensive support of the 68K family advanced exception/interrupt system. You can install routines to handle particular exceptions using various OS9 system calls for the types of exceptions.

Table 2.B
Vector Descriptions for 68000/008/010/070/CPU32 Family

Vector number:	Related OS-9 call:	Assignment:
0	none	Reset initial Supervisor Stack Pointer (SSP)
1	none	Reset initial Program Counter (PC)
2	F$STrap	Bus error
3	F$STrap	Address error
4	F$STrap	Illegal instruction
5	F$STrap	Zero divide
6	F$STrap	CHK instruction; CHK2 (CPU32)
7	F$STrap	TRAPV instruction
8	F$STrap	Privilege violation
9	F$DFork	Trace
10	F$STrap	Line 1010 emulator
11	F$STrap	Line 1111 emulator
12	none	Reserved (000/008/010/070); hardware break point (CPU32)
13	none	Reserved
14	none	Reserved (000/008); format error (010/070/CPU32)
15	none	Uninitialized interrupt
16-23	none	Reserved
24	none	Spurious interrupt
25-31	F$IRQ	Level 1-7 interrupt autovectors
32	F$OS9	User TRAP #0 instruction (OS-9 call)
33-47	F$TLink	User TRAP #1-15 instruction vectors
48-56	none	Reserved
57-63	none/F$IRQ	Reserved (000/008/010/CPU32) on-chip level 1-7 auto-vectored interrupts (070)
64-255	F$IRQ	Vectored interrupts (user defined)

Table 2.C
Vector Descriptions for 68020/030/040

Vector number:	Related OS-9 call:	Assignment:
0	none	Reset initial Supervisor Stack Pointer (SSP)
1	none	Reset initial Program Counter (PC)
2	F$STrap	Bus error
3	F$STrap	Address error
4	F$STrap	Illegal instruction
5	F$STrap	Zero divide
6	F$STrap	CHK, CHK2
7	F$STrap	TRAPV cpTRAPcc, TRAPcc
8	F$STrap	Privilege violation
9	F$DFork	Trace
10	F$STrap	Line 1010 emulator
11	F$STrap	Line 1111 emulator
12	none	Reserved
13	none	Coprocessor protocol violation (020,030 only); reserved (040)
14	none	Format error
15	none	Uninitialized interrupt
16-23	none	Reserved
24	none	Spurious interrupt
25-31	F$IRQ	Level 1-7 interrupt autovectors
32	F$OS9	User TRAP #0 instruction (OS-9 call)
33-47	F$TLink	User TRAP #1-15 instruction vectors
48	F$STrap	FPCP Branch, or set on unordered condition
49	F$STrap	FPCP Inexact result
50	F$STrap	FPCP Divide by zero
51	F$STrap	FPCP Underflow error
52	F$STrap	FPCP Operand error
53	F$STrap	FPCP Overflow error
54	F$STrap	FPCP NAN signaled
55	F$STrap	Reserved (020/030); FPCP Unimplemented data type (040)
56	none	PMMU Configuration (020/030); reserved (040)
57	none	PMMU Illegal Operation (020); reserved (030/040)
58	none	PMMU Access Level Violation (020); reserved (030/040)
59-63	none	Reserved
64-255	F$IRQ	Vectored interrupts (user defined)

Reset Vectors: vectors 0, 1

The reset initial SSP vector contains the address loaded into the system's stack pointer at startup. There must be at least 4K of RAM below and 4K of RAM above this address for system global storage. Each time an exception occurs, OS-9 uses this vector to find the base address of system global data.

The reset initial program counter (PC) is the coldstart entry point to OS-9. After startup, its only use is to reset after a catastrophic failure.

ATTENTION: User programs should not use or modify either of these vectors.

Error Exceptions: vectors 2-8, 10-24, 48-63

These exceptions are usually considered fatal program errors and cause a user program to unconditionally terminate. If F$DFork created the process, the process resources remain intact and control returns to the parent debugger to allow a postmortem examination.

You may use the F$STrap system call to install a user subroutine to catch the errors in this group that are considered non-fatal.

When an error exception occurs, the user subroutine executes in user state, with a pointer to the normal data space used by the process and all user registers stacked. The exception handler must decide whether and where to continue execution.

If any of these exceptions occur in system state, it usually means a system call was passed bad data and an error is returned. In some cases, system data structures are damaged by passing nonsense parameters to system calls.

Important: Not all catchable exception vectors are applicable to all 68000-family CPUs. For example, vectors 48-54 (FPCP exceptions) only apply to 68020 and 68030 CPUs.

The Trace Exception: vector 9

The trace exception occurs when the status register trace bit is set. This allows the MPU to single step instructions. OS-9 provides the F$DFork, F$DExec, and F$DExit system calls to control program tracing.

AutoVectored Interrupts: vectors 25-31; 57-63 (68070 only)

These exceptions provide interrupt polling for I/O devices that do not generate vectored interrupts. Internally, they are handled exactly like vectored interrupts (see below).

ATTENTION: Normally, you should not use Level 7 interrupts because they are non-maskable and can interrupt the system at dangerous times. You may use Level 7 interrupts for software refresh of dynamic RAMs or similar functions, provided that the IRQ service routine does not use any OS-9 system calls or system data structures.

User Traps: vectors 32-47

The system reserves user trap zero (vector 32) for standard OS-9 system service requests. The remaining 15 user traps provide a method to link to common library routines at execution time.

Library routines are similar to program object code modules and are allocated their own static storage when installed by the F$TLink service request. The execution entry point executes whenever the user trap is called. In addition, trap handlers have initialization and termination entry points which execute when linked and at process termination. The termination entry point is not currently implemented.

Important: Trap 13 (CIO) and trap 15 (math) are standard trap handlers distributed by Microware.

Vectored Interrupts: vectors 64-255

The 192 vectored interrupts provide a minimum amount of system overhead in calling a device driver module to handle an interrupt. Interrupt service routines execute in system state without an associated current process. The device driver must provide an error entry point for the system to execute if any error exceptions occur during interrupt processing, although this entry point is not currently implemented. The F$IRQ system call installs a handler in the system's interrupt tables. If necessary, multiple devices may be used on the same vector.

Chapter 3

OS-9 Input/Output System

The OS-9 Unified Input/Output System

OS-9 features a versatile, unified, hardware-independent I/O system. The I/O system is modular; you can easily expand or customize it. The OS-9 I/O system consists of the following software components:

- the kernel
- file managers
- device drivers
- the device descriptor

The kernel, file managers, and device drivers process I/O service requests at different levels. The device descriptor contains information used to assemble the elements of a particular I/O subsystem. The file manager, device driver, and device descriptor modules are standard memory modules. You can install or remove any of these modules while the system is running.

The kernel supervises the overall OS-9 I/O system. The kernel:

- maintains the I/O modules by managing various data structures. It ensures that the appropriate file manager and device driver modules process each I/O request.

- establishes paths. These are the connections between the kernel, the application, the file manager, and the device driver.

File managers perform the processing for a particular class of devices, such as disks or terminals. They deal with “logical” operations on the class of devices. For example, the Random Block File manager (RBF) maintains directory structures on disks; the Sequential Character File manager (SCF) edits the data stream it receives from terminals. File managers deal with the I/O requests on a generic “class” basis.

Device drivers operate on a class of hardware. Operating on the actual hardware device, they send data to and from the device on behalf of the file manager. They isolate the file manager from hardware dependencies such as control register organization and data transfer modes, translating the file manager’s logical requests into specific hardware operations.

The device descriptor contains the information required to assemble the various components of an I/O subsystem (that is, a device). It contains the names of the file manager and device driver associated with the device, as well as the device's operating parameters. Parameters in device descriptors can be fixed, such as interrupt level and port address, or variable, such as terminal editing settings and disk physical parameters. The variable parameters in device descriptors provide the initial default values when a path is opened, but applications can change these values. The device descriptor name is the name of a device as known by the user. For example, the device /d0 is described by the device descriptor d0.

The Kernel and I/O

The kernel provides the first level of service for I/O system calls by routing data between processes and the appropriate file managers and device drivers. The kernel also allocates and initializes global static storage on behalf of file managers and device drivers.

The kernel maintains two important internal data structures: the device table and the path table. These tables reflect two other structures respectively: the device descriptor and the path descriptor.

When a path is opened, the kernel attempts to link to the device descriptor associated with the device name specified (or implied) in the pathlist. The device descriptor contains the names of the device driver and file manager for the device. The information in the device descriptor is saved by the kernel in the device table so that it can route subsequent system calls to these modules.

Paths maintain the status of I/O operations to devices and files. The kernel maintains these paths using the path table. Each time a path is opened, a path descriptor is created and an entry is added to the path table. When a path is closed, the path descriptor is de-allocated and its entry is deleted from the path table.

When an I$Attach system call is first performed on a new device descriptor, the kernel creates a new entry in the device table. Each entry in the table has specific information from the device descriptor concerning the appropriate file manager and driver. It also contains a pointer to the device driver static storage. For each device in the table, the kernel maintains a use count which indicates the current number of device users.

Device Descriptor Modules

Device descriptor modules are small, non-executable modules that contain information to associate a specific I/O device with its logical name, hardware controller address(es), device driver name, file manager name, and initialization parameters.

File managers operate on a class of **logical** devices. Device drivers operate on a class of **physical** devices. A device descriptor module tailors a device driver or file manager to a specific I/O port. At least one device descriptor module must exist for each I/O device in the system. An I/O device may have several device descriptors with different initialization parameters and names. For example, a serial/parallel driver could have two device descriptors, one for terminal operation (/T1) and one for printer operation (/P1).

If a suitable device driver exists, adding devices to the system consists of adding the new hardware and another device descriptor. Device descriptors can be in ROM, in the boot file, or loaded into RAM while the system is running.

The name of the module is used as the logical device name by the system and user (that is, it is the device name given in pathlists). Its format consists of a standard module header that has a type code of device descriptor (DEVIC). The remaining module header fields are shown in Figure 3.1 and described below.

Important: These fields are standard for all device descriptor modules. They are followed by a device specific initialization table. Refer to Appendix B of this manual for the initialization tables of each standard class of I/O devices (RBF, SCF, SBF).

Name:	Description:
M$Port	**Port address** The absolute physical address of the hardware controller.
M$Vector	**Interrupt vector number** The interrupt vector associated with the port, used to initialize hardware and for installation on the IRQ poll table: 25-31 for an auto-vectored interrupt. Levels 1-7. 57-63 for 68070 on-chip auto-vectored interrupts. Levels 1-7. 64-255 for a vectored interrupt.
M$IRQLvl	**Interrupt level** The device's physical interrupt level. It is *not* used by the kernel or file manager. The device driver may use it to mask off interrupts for the device when critical hardware manipulation occurs.
M$Prior	**Interrupt polling priority** Indicates the priority of the device on its vector. Smaller numbers are polled first if more than one device is on the same vector. A priority of zero indicates the device requires exclusive use of the vector.
M$Mode	**Device mode capabilities** This byte is used to validate a caller's access mode byte in I$Create or I$Open calls. If the bit is set, the device is apable of performing the corresponding function. If the Share_bit (single user bit) is set here, the device is non-sharable. This is useful for printers.
M$FMgr	**File manager name offset** The offset to the name string of the file manager module for this device.
M$PDev	**Device driver name offset** The offset to the name string of the device driver module for this device.
M$DevCon	**Device configuration** The offset to an optional device configuration table. You can use it to specify parameters or flags that the device driver needs and are not part of the normal initialization table values. This table is located after the standard initialization table. The kernel or file manager never references it. As the pointer to the device descriptor is passed in INIT and TERM, M$DevCon is generally available to the driver only during the driver's INIT and TERM routines. Other routines in the driver (for example, Read) must first search the device table to locate the device descriptor before they can access this field. Typically, this table is used for name string pointers, OEM global allocation pointers, or device-specific constants/flags. NOTE: These values, unlike the standard options, are not copied into the path descriptors options section.
M$Opt	**Table size** This contains the size of the device's standard initialization table. Each file manager defines a ceiling on M$Opt.
M$DTyp	**Device type (first field of initialization table)** The device's standard initialization table is defined by the file manager associated with the device, with the exception of the first byte (M$DTyp). The first byte indicates the class of the device (RBF, SCF, etc.). The initialization table (M$DTyp through M$DTyp **+** M$Opt) is copied into the option section of the path descriptor when a path to the device is opened. Typically, this table is used for the default initialization parameters such as the delete and backspace characters for a terminal. Applications may examine all of the values in this table using $GetStt (SS_Opt). Some of the values may be changed using I$SetStt; some are protected by the file manager to prevent inappropriate changes. The theoretical maximum initialization table size is 128 bytes. However, a file manager may restrict this to a smaller value.

Important: Offset refers to the location of a module field, relative to the starting address of the module. Module offsets are resolved in assembly code by using the names shown here and linking with the relocatable library: sys.l or usr.l.

Figure 3.1
Additional Standard Header Fields for Device Descriptors

Offset:	Name:	Usage:
$30	M$Port	Port Addres
$34	M$Vector	Trap Vector Number
$35	M$IRQLvl	IRQ Interrupt Level
$36	M$Prior	IRQ Polling Priority
$37	M$Mode	Device Mode Capabilities
$38	M$FMgr	File Manager Name Offset
$3A	M$PDev	Device Driver Name Offset
$3C	M$DevCon	Device Configuration Offset
$3E		Reserved
$46	M$Opt	Initialization Table Size
$48	M$DTyp	Device Type

You may wish to add additional devices to your system. If an identical device controller already exists, simply add the new hardware and another device descriptor. Device descriptors can be in ROM, in the boot file, or loaded into RAM from mass storage files while the system is running.

Path Descriptors

Every open path is represented by a data structure called a path descriptor. It contains information required by file managers and device drivers to perform I/O functions. Path descriptors are dynamically allocated and de-allocated as paths are opened and closed.

Path descriptors have three sections:

- The first 30 bytes are defined universally for all file managers and device drivers.
- PD_FST is reserved for and defined by each type of file manager for file pointers, permanent variables, etc.
- PD_OPT is a 128-byte option area used for dynamically alterable operating parameters for the file or device. These variables are initialized at the time the path is opened by copying the initialization table contained in the device descriptor module, and can be examined or altered later by user programs via GetStat and SetStat system calls. Not all options can be modified.

Refer to Appendix B for the current definitions of the path descriptor option area for each standard class of I/O devices (that is, RBF, SCF, SBF, and Pipes). The definitions are included in sys.l or usr.l, and are linked into programs that need them.

Important: Offset refers to the location of a module field, relative to the starting address of the module. Module offsets are resolved in assembly code by using the names shown here and linking the module with the relocatable libraries, sys.l, or usr.l.

Table 3.A
Universal Path Descriptor Definitions

Offset:	Name:	Maintained by:	Description:
$00	PD_PD	Kernel	Path Number
$02	PD_MOD	Kernel	Access Mode (R W E S D)
$03	PD_CNT	Kernel	Number of Paths using this PD (obsolete)
$04	PD_DEV	Kernel	Address of Related Device Table Entry
$08	PD_CPR	Kernel	Requester's Process ID
$0A	PD_RGS	Kernel	Address of Caller's MPU Register Stack
$0E	PD_BUF	File Manager	Address of Data Buffer
$12	PD_USER	Kernel	Group/User ID of Original Path Owner
$16	PD_PATHS	Kernel	List of Open Paths on Device
$1A	PD_COUNT	Kernel	Number of Paths using this PD
$1C	PD_LProc	Kernel	Last Active Process ID
$20	PD_ErrNo	File Manager	Global "errno" for C language file managers
$24	PD_SysGlob	File Manager	System global pointer for C language file managers
$2A	PD_FST	File Manager	File Manager Working Storage
$80	PD_OPT	Driver/File Man.	Option Table

File Managers

File managers process the raw data stream to or from device drivers for a class of similar devices. File managers make device drivers conform to the OS-9 standard I/O and file structure by removing as many unique device operational characteristics as possible from I/O operations. They are also responsible for mass storage allocation and directory processing, if applicable, to the class of devices they service.

File managers usually buffer the data stream and issue requests to the kernel for dynamic allocation of buffer memory. They may also monitor and process the data stream. For example, they may add line feed characters after carriage return characters.

File managers are re-entrant. One file manager may be used for an entire class of devices having similar operational characteristics. OS-9 systems can have any number of file manager modules.

Important: I/O system modules must have the following module attributes:

- They must be owned by a super-user (0.n).
- They must have the system-state bit set in the attribute byte of the module header. (OS-9 does not currently make use of this, but future revisions will require that I/O system modules be system-state modules.)

Four file managers are included in a typical OS-9 system:

RBF (Random Block File Manager)
Operates random-access, block-structured devices such as disk systems.

SCF (Sequential Character File Manager)
Used with single-character-oriented devices such as CRT or hardcopy terminals, printers, and modems.

SBF (Sequential Block File Manager)
Used with sequential block-structured devices such as tape systems.

PIPEMAN (Pipe File Manager)
Supports interprocess communication through memory buffers called pipes.

File Manager Organization

A file manager is a collection of major subroutines accessed through an offset table. The table contains the starting address of each subroutine relative to the beginning of the table. The location of the table is specified by the execution entry point offset in the module header. These routines are called in system state. A sample listing of the beginning of a file manager module is listed in Figure 3.2.

When the individual file manager routines are called, standard parameters are passed in the following registers:

Parameter:	Description:
(a1)	Pointer to Path Descriptor
(a4)	Pointer to current Process Descriptor
(a5)	Pointer to User's Register Stack; User registers pass/receive parameters as shown in the system call description section
(a6)	Pointer to system Global Data area

Figure 3.2
Beginning of a Sample File Manager Module

```
* Sample File Manager
* Module Header declaration
      Type_Lang equ (FlMgr<<8)+Objct
      Attr_Revs equ ((ReEnt+Supstat)<<8)+0

      psect
FileMgr,Type_Lang,Attr_Revs,Edition,0,Entry_pt

* Entry Offset Table
Entry_pt dc.w            Create–Entry_pt
      dc.w               Open–Entry_pt
      dc.w               MakDir–Entry_pt
      dc.w               ChgDir–Entry_pt
      dc.w               Delete–Entry_pt
      dc.w               Seek–Entry_pt
      dc.w               Read–Entry_pt
      dc.w               Write–Entry_pt
      dc.w               ReadLn–Entry_pt
      dc.w               WriteLn–Entry_pt
      dc.w               GetStat–Entry_pt
      dc.w               SetStat–Entry_pt
      dc.w               Close–Entry_pt
* Individual Routines Start Here
```

File Manager I/O Responsibilities

Name:	Description:
Open	Opens a file on a particular device. This typically involves allocating any buffers required, initializing path descriptor variables, and parsing the path name. If the file manager controls multi-file devices (RBF, PIPEMAN), directory searching is performed to find the specified file.
Create	Performs the same function as Open. If the file manager controls multi-file devices (RBF, PIPEMAN), a new file is created.
Makdir	Creates a directory file on multi-file devices. Makdir is neither preceded by a Create nor followed by a Close. File managers that are incapable of supporting directories return with the carry bit set and an appropriate error code in register d1.w.
Chgdir	On multi-file devices, ChgDir searches for a directory file. If the directory is found, the address of the directory is saved in the caller's process descriptor at P$DIO. The kernel allocates a path descriptor so that the ChgDir function may save information about the directory file for later searching. Open and Create begin searching in this directory when the caller's pathlist does not begin with a slash (**/**) character. File managers that do not support directories return with the carry bit set and an appropriate error code in register d1.w.

Name:	Description:
Delete	Multi-file device managers usually do a directory search that is similar to Open and, once found, remove the file name from the directory. Any media that was in use by the file is returned to unused status. File managers that do not support multi-file devices return an E_UNKSVC error.
Seek	File managers that support random access devices use Seek to position file pointers of the already open path to the specified byte. Typically, this is a logical movement and does not affect the physical device. No error is produced at the time of the Seek, if the position is beyond the current end of file. File managers that do not support random access usually do nothing, but do not return an E_UNKSVC error.
Read	Read returns the number of bytes requested to the user's data buffer. If there is no data available, an EOF error is returned. Read must be capable of copying pure binary data. It generally does not perform editing on data. Usually, the file manager calls the device driver to actually read the data into a buffer. It then copies data from the buffer into the user's data area. This method helps keep file managers device independent.
Write	The Write request, like Read, must be capable of recording pure binary data without alteration. Usually, the Read and Write routines are nearly identical. The most notable difference is that Write uses the device driver's output routine instead of the input routine. Writing past the end of file on a device expands the file with new data. RBF and similar random access devices that use fixed-length records (sectors) must often pre-read a sector before writing it unless the entire sector is being written.
Readln	ReadLn differs from Read in two respects. First, ReadLn is expected to terminate when the first end-of-line character (carriage return) is encountered. Second, ReadLn performs any input editing that is appropriate for the device. Specifically, the SCF File Manager performs editing that involves handling backspace, line deletion, echo, etc.
Writeln	Writeln is the counterpart of Readln. It calls the device driver to transfer data up to and including the first (if any) carriage return encountered. Appropriate output editing also is performed. After a carriage return, for example, SCF usually outputs a line feed character and nulls (if appropriate).
Getstat	The Getstat (Get Status) system call is a wild card call designed to provide the status of various features of a device (or file manager) that are not generally device independent. The file manager may perform some specific function such as obtaining the size of a file. Status calls that are unknown by the file manager are passed to the driver to provide a further means of device independence.
Setstat	Setstat (Set Status) is the same as the Getstat function except that it is generally used to set the status of various features of a device (or file manager). The file manager may perform some specific function such as setting the size of a file to a given value. Status calls that are unknown by the file manager are passed to the driver to provide a further means of device independence. For example, a SetStat call to format a disk track may behave differently on different types of disk controllers.
Close	Close ensures that any output to a device is completed (writing out the last buffer if necessary), and releases any buffer space allocated when the path was opened. It may do specific end-of-file processing if necessary, such as writing end-of-file records on tapes.

Device Driver Modules

Device driver modules perform basic low-level physical input/output functions. For example, a disk driver module's basic functions are to read or write a physical sector. The driver is not concerned about files, directories, etc., which are handled at a higher level by the OS-9 file manager. Because device driver modules are re-entrant, one copy of the module can simultaneously support multiple devices that use identical I/O controller hardware.

This section describes the function and general design of OS-9 device driver modules to aid programmers in modifying existing drivers or writing new ones. To present this information in an understandable manner, only basic drivers for character-oriented (SCF-type) and disk-oriented (RBF-type) devices are discussed. We recommend that you study this section in conjunction with the individual device-specific sections and sample device driver source listings included in the OS-9 Technical I/O Manual.

Basic Functional Requirements of Drivers

If written properly, a single physical driver module can handle multiple identical hardware interfaces. The specific information for each physical interface (port address, initialization constants, etc.) is provided in the device descriptor module.

The name by which the device is known to the system is the name of the device descriptor module. OS-9 copies the initialization data of the device descriptor to the path descriptor data structure for easy access by the drivers.

A device driver is actually a package of seven subroutines that are called by a file manager in system state. Their functions are:

- initialize the device controller hardware and related driver variables as required
- read a standard physical unit (a character or sector, depending on the device type)
- write a standard physical unit (a character or sector, depending on the device type)
- return a specified device status
- set a specified device status
- de-initialize the device. It is assumed that the device will not be used again unless re-initialized.
- process an error exception generated during driver execution

The interrupt service subroutine is also part of the device driver, although it is not called by the file manager, but by the kernel's interrupt routine. It communicates with the driver's main section through the static storage and certain system calls.

Driver Module Format

All drivers must conform to the standard OS-9 memory module format. The module type code is Drivr. Drivers should have the system-state bit set in the attribute byte of the module header. Currently OS-9 does not make use of this, but future revisions will require all device drivers to be system state modules. A sample assembly language header is shown in Figure 3.3.

The execution offset in the module header (M$Exec) gives the address of an **offset table**, which specifies the starting address of each of the seven driver subroutines relative to the base address of the module.

The static storage size (M$Mem) specifies the amount of local storage required by the driver. This is the sum of the global I/O storage, the storage required by the file manager (V_xxx variables), and any variables and tables declared in the driver.

The driver subroutines are called by the associated file manager through the offset table. The driver routines are always executed in system state. Regardless of the device type, the standard parameters listed below are passed to the driver in registers. Other parameters that depend on the device type and subroutine called may also be passed. These are described in individual chapters concerning file managers in the OS-9 Technical I/O Manual.

Parameter:	Description:
INITIALIZE and TERMINATE	
(a1)	address of the device descriptor module
(a2)	address of the driver's static variable storage
(a4)	address of the process descriptor requesting the I/O function
(a6)	address of the system global variable storage area
READ, WRITE, GETSTAT and SETSTAT	
(a1)	address of the path descriptor
(a2)	address of the driver's static variable storage
(a4)	address of the process descriptor requesting the I/O function
(a5)	pointer to the calling process' register stack
(a6)	address of the system global variable storage area
ERROR	
This entry point should be defined as the offset to error exception handling code or zero if no handler is available. This entry point is currently not used by the kernel. However, it will be accessed in future revisions.	

Each subroutine is terminated by a RTS instruction. Error status is returned using the CCR carry bit with an error code returned in register d1.w.

Figure 3.3
Sample Driver Module Header Format

```
* Module Header

Type_Lang equ (Drivr<<8)+Objct
Attr_Revs equ ((ReEnt+Supstat)<<8)+0

psect Acia,Typ_Lang,Attr_Rev,Edition,0,AciaEnt

* Entry Point Offset Table
AciaEnt      dc.w         Init         Initialization routine offset
             dc.w         Read         Read routine offset
             dc.w         Write        Write routine offset
             dc.w         GetStat      Get dev status routine offset
             dc.w         SetStat      Set dev status routine offset
             dc.w         TrmNat       Terminate dev routine offset
             dc.w         Error        Error handler routine offset (0=none)
```

Interrupts and DMA

Because OS-9 is a multi-tasking operating system, you obtain optimum system performance when all I/O devices are set up for interrupt-driven operation.

For character-oriented devices, set up the controller to generate an interrupt upon the receipt of an incoming character and at the completion of transmission of an out-going character. Both the input data and the output data should be buffered in the driver.

In the case of block-type devices (for example, RBF, SBF), set up the controller to generate an interrupt upon the completion of a block read or write operation. It is not necessary for the driver to buffer data because the driver is passed the address of a complete buffer. Direct Memory Access (DMA) transfers, if available, significantly improve data transfer speed.

Usually, the Init routine adds the relevant device interrupt service routine to the OS-9 interrupt polling system using the F$IRQ system call. The controller interrupts are enabled and disabled by the READ and WRITE routines as required. TERM disables the physical interrupts and then takes the device off the interrupt polling table.

The assignment of device intercept priority levels can have a significant impact on system operation. Generally, the smarter the device, the lower you can set its interrupt level. For example, a disk controller that buffers sectors can wait longer for service than a singlecharacter buffered serial port. Assign the Clock tick device the highest possible level to keep system time-keeping interference at a minimum.

The following table shows how you can assign interrupt levels:

```
level  6: clock ticker
       5:     “dumb” (non–buffering) disk controller
       4:     terminal port
       3:     printer port
       2:     “smart” (sector–buffering) disk controller
```

Chapter 4

Interprocess Communications

This chapter describes the five forms of interprocess communication that OS-9 supports:

- signals
- alarms
- events
- pipes
- data modules

Signals synchronize concurrent processes. Alarms send signals or execute subroutines at specified times. Events synchronize concurrent processes' access of shared resources. Pipes transfer data among concurrent processes. Data modules transfer or share data among concurrent processes.

Signals

In interprocess communications, a **signal** is an intentional disturbance in a system. OS-9 signals are designed to synchronize concurrent processes, but you can also use them to transfer small amounts of data. Because they are usually processed immediately, signals provide real-time communication between processes.

Signals are also referred to as **software interrupts** because a process receives a signal similar to a CPU receiving an interrupt. Signals enable a process to send a "numbered interrupt" to another process. If an active process receives a signal, the intercept routine executes immediately (if installed) and the process resumes execution where it left off. If a sleeping or waiting process receives a signal, the process moves to the active queue, the signal routine executes, and the process resumes execution immediately after the call that removed it from the active queue.

Important: A process which receives a signal for which it does not have an intercept routine is killed. This applies to all signals greater than 1 (wake-up signal).

Each signal has two parts:

- the process ID of the destination
- a signal code

OS-9 supports the following signal codes in user-state:

Signal:	Description:
0	Unconditional system abort signal. The super-user can send the kill signal to any process, but non-super-users can send this signal only to processes with their group and user IDs. This signal terminates the receiving process, regardless of the state of its signal mask, and is not intercepted by the intercept handler.
1	Wake-up signal. Sleeping/waiting processes which receive this signal are awakened, but the signal is not intercepted by the intercept handler. Active processes ignore this signal. A program can receive a wake-up signal safely without an intercept handler. The wake-up signal is not queued if the process's signals are masked.
2	Keyboard abort signal. Typing control-E sends this signal to the last process to do I/O on the terminal. Usually, the intercept routine performs exit(2) upon receiving a keyboard abort signal.
3	Keyboard interrupt signal. Typing control-C sends this signal to the last process to do I/O on the terminal. Usually, the intercept routine performs exit(3) upon receiving a keyboard interrupt signal.
4	Hang-up signal. SCF sends this signal when it discovers that the modem connection is lost.
5-31	These signal numbers are reserved for future use by Microware. Signals in this range are considered deadly to the I/O system.
32-255	These signal numbers are reserved for future use by Microware.
256-65535	User-defined signals. These signal numbers are available for use in user applications.

You could design a signal routine to interpret the signal code word as data. For example, you could send various signal codes to indicate different stages in a process's execution. This is extremely effective because signals are processed immediately upon receipt.

The following system calls enable processes to communicate through signals:

Name:	Description:
F$Send	Sends a signal to a process.
F$Icpt	Installs a signal intercept routine.
F$Sleep	Deactivates the calling process until the specified number of ticks has passed or a signal is received.
F$SigMask	Enables/disables signals from reaching the calling process.

For specific information about these system calls, refer to Appendix D, OS-9 System Calls. The Microware C Compiler supports a corresponding C call for each of these calls, as well.

Important: Appendix A contains a program which demonstrates how you may use signals.

Alarms

User-state Alarms

The user-state F$Alarm request allows a program to arrange to send a signal to itself. The signal may be sent at a specific time of day or after a specified interval passes. The program may also request that the signal be sent periodically, each time the specified interval passes.

OS-9 supports the following user-state alarm functions:

Name:	Description:
A$Delete	Remove a pending alarm request
A$Set	Send a signal after specified time interval
A$Cycle	Send a signal at specified time intervals
A$AtDate	Send a signal at Gregorian date/time
A$AtJul	Send a signal at Julian date/time

Cyclic Alarms

A cyclic alarm is most useful for providing a time base within a program. This greatly simplifies the synchronization of certain time-dependent tasks. For example, a real-time game or simulation might allow 15 seconds for each move. You could use a cyclic alarm signal to determine when to update the game board.

The advantages of using cyclic alarms are more apparent when multiple time bases are required. For example, suppose that you were using an OS-9 process to update the real-time display of a car's digital dashboard. The process might need to:

- update a digital clock display every second
- update the car's speed display five times per second
- update the oil temperature and pressure display twice per second
- update the inside/outside temperature every two seconds
- calculate miles to empty every five seconds

You could give each function the process must monitor a cyclic alarm, whose period is the desired refresh rate, and whose signal code identifies the particular display function. The signal handling routine might read an appropriate sensor and directly update the dashboard display. The system takes care of all of the timing details.

Time of Day Alarms

You can set an alarm to provide a signal at a specific time and date. This provides a convenient mechanism for implementing a “cron” type of utility, which executes programs at specific days and times. Another use is to generate a traditional alarm clock buzzer for personal reminders.

A key feature of this type of alarm is that it is sensitive to changes made to the system time. For example, assume the current time is 4:00 and you want a program to send itself a signal at 5:00. The program could either set an alarm to occur at 5:00 or set the alarm to go off in one hour. Assume the system clock is 30 minutes slow, and the system administrator corrects it. In the first case, the program wakes up at 5:00; in the second case, the program wakes up at 5:30.

Relative Time Alarms

You can use a relative time alarm to set a time limit for a specific action. Relative time alarms are frequently used to cause an I$Read request to abort if it is not satisfied within a maximum time. Do this by sending a keyboard abort signal at the maximum allowable time, and then issuing the I$Read request. If the alarm arrives before the input is received, the I$Read request returns with an error. Otherwise, the alarm should be cancelled. The example program deton.c in Appendix A demonstrates this technique.

System-state Alarms

A system-state counterpart exists for each of the user-state alarm functions. However, the system-state version is considerably more powerful than its user-state equivalent. When a user-state alarm expires, the kernel sends a signal to the requesting process. When a system-state alarm expires, the kernel executes the system-state subroutine specified by the requesting process at a very high priority.

OS-9 supports the following system-state alarm functions:

Name:	Description:
A$Delete	Remove a pending alarm request
A$Set	Execute a subroutine after a specified time interval
A$Cycle	Execute a subroutine at specified time intervals
A$AtDate	Execute a subroutine at a Gregorian date/time
A$AtJul	Execute a subroutine at Julian date/time

Important: The alarm is executed by the kernel's process, not by the original requester's process. During execution, the user number of the system process temporarily changes to the original requester. The stack pointer (a7) passed to the alarm subroutine is within the system process descriptor, and contains about 1K of free space.

The kernel automatically deletes a process's pending alarm requests when the process terminates. This may be undesirable in some cases. For example, assume an alarm is scheduled to shut off a disk drive motor if the disk has not been accessed for 30 seconds. The alarm request is made in the disk device driver on behalf of the I/O process. This alarm does not work if it is removed when the process exits.

One way to arrange for a persistent alarm is to execute the F$Alarm request on behalf of the system process, rather than the current I/O process. Do this by moving the system variable D_SysPrc to D_Proc, executing the alarm request, and restoring D_Proc. For example:

```
move.l D_Proc(a6),-(a7)              save current process pointer
movea.l D_SysPrc(a6),D_Proc(a6)      impersonate system process
OS9 F$Alarm                            execute the alarm request
/*  (error handling omitted)  */
move.l (a7)+,D_Proc(a6)                restore current process
```

ATTENTION: If you use this technique, you must ensure that the module containing the alarm subroutine remains in memory until after the alarm has expired.

An alarm subroutine must not perform any function that could result in any kind of sleeping or queuing. This includes F$Sleep, F$Wait, F$Load, F$Event (wait), F$IOQU, and F$Fork (if it might require F$Load). Other than these functions, the alarm subroutine may perform any task.

One possible use of the system-state alarm function might be to poll a positioning device, such as a mouse or light pen, every few system ticks. Be conservative when scheduling alarms, and make the cycle as large as reasonably possible. Otherwise, a great deal of the system's available CPU time could be wasted.

Important: Refer to Appendix A for a program demonstrating how you can use alarms.

Events

OS-9 **events** are multiple-value semaphores. They synchronize concurrent processes which are accessing shared resources such as files, data modules, and CPU time. For example, if two processes need to communicate with each other through a common data module, you may need to synchronize the processes so that only one updates the data module at a time.

Events do not transmit any information, although processes using the event system may obtain information about the event, and use it as something other than a signaling mechanism.

An OS-9 event is a 32-byte system global variable maintained by the system. Each event includes the following fields:

Field:	Description:
Event ID	This number and the event's array position create a unique ID.
Event name	This name must be unique and cannot exceed 11 characters.
Event value	This four-byte integer value has a range of 2 billion.
Wait increment	This value is added to the event value when a process waits for the event. It is set when the event is created and does not change.
Signal increment	This value is added to the event value when the event is signaled. It is set when the event is created and does not change.
Link Count	This is the event use count.
Next event	This is a pointer to the next process in the event queue. An event queue is circular and includes all processes waiting for the event. Each time the event is signaled, this queue is searched.
Previous event	This is a pointer to the previous process in the event queue.

The OS-9 event system provides facilities to create and delete events, to permit processes to link/unlink events and obtain event information, to suspend operation until an event occurs, and for various means of signaling.

You may use events directly as service requests in assembly language programs. The Microware C compiler supports a corresponding C call for each event system call.

The Wait and Signal Operations

Wait and Signal are the two most common operations performed on events. The Wait operation suspends the process until the event is within a specified range, adds the wait increment to the current event value, and returns control to the process just after the wait operation was called. The Signal operation adds the signal increment to the current event value, checks for other processes to awaken, and returns control to the process. These operations allow a process to suspend itself while waiting for an event and to reactivate when another process signals that the event has occurred.

For example, you could use events to synchronize the use of a printer. Initialize the event value to one, the number of printers on the system. Set the signal increment to one, and the wait increment to minus one (–1). When a process wants to use the printer, it checks to see if one is available, that is, it waits for the event value to be in the range (1, number of printers). In this example, the number of printers is one.

An event value within the specified range indicates that the printer is available; the printer is immediately marked as busy (that is, the event value increases by –1, the wait increment) and the process is allowed to use it. An event value out of range indicates that the printer is busy and the process is put to sleep on the event queue.

When a process finishes with the printer, the process signals the event, that is, it applies the signal increment to the event value. Then, the event queue is searched for a process whose event value range includes the current event value. If such a process is found, the process activates, applies the wait increment to the event value, and uses the printer.

To coordinate sharing a non-sharable resource, user programs must:

- wait for the resource to become available
- mark the resource as busy
- use the resource
- signal that the resource is no longer busy

The first two steps in this process must be indivisible, because of time-slicing. Otherwise, two processes could check an event and find it free. Then, both processes would try to mark it busy. This corresponds to two processes using a printer at the same time. The F$Event service request prevents this from happening by performing both steps in the Wait operation.

Important: Appendix A includes a program which demonstrates how you may use events.

The F$Event System Call

The F$Event system call provides the mechanism to create named events for this type of application. The name “event” was chosen instead of “semaphore” because F$Event provides the flexibility to synchronize processes in a variety of ways not usually found in semaphore primitives. OS-9’s event routines are very efficient, and suitable for use in real-time control applications.

Event variables require several maintenance functions as well as the Signal and Wait operations. To keep the number of system calls required to a minimum, all event operations are accessible through the F$Event system call.

Currently, OS-9 has functions to allow you to create, delete, link, unlink, and examine events (listed below). It also provides several variations of the Signal and Wait operations.

The F$Event description in Appendix D, OS-9 System Calls discusses specific parameters and functions of each event operation. The system definition file funcs.a defines Ev$ function names. Resolve actual values for the function codes by linking with the relocatable library sys.l or usr.l.

OS-9 supports the following event functions:

Function:	Description:
Ev$Link	Link to an existing event by name.
Ev$UnLnk	Unlink an event.
Ev$Creat	Create a new event.
Ev$Delet	Delete an existing event.
Ev$Wait	Wait for an event to occur.
Ev$WaitR	Wait for a relative to occur.
Ev$Read	Read an event value without waiting.
Ev$Info	Return event information.
Ev$Pulse	Signal an event occurrence. Temporarily changes the event value.
Ev$Signl	Signal an event occurrence. Changes the event value.
Ev$Set	Set an event variable and signal an event occurrence.
Ev$SetR	Set a relative event variable and signal an event occurrence.

Pipes

An OS-9 **pipe** is a first-in first-out (FIFO) buffer which enables concurrently executing processes to communicate data: the output of one process (the writer) is read as input by a second process (the reader). Communication through pipes eliminates the need for an intermediate file to hold data.

Pipeman is the OS-9 file manager that supports interprocess communication through pipes. Pipeman is a re-entrant subroutine package that is called for I/O service requests to a device named /pipe. Although no physical device is used in pipe communications, a driver must be specified in the pipe descriptor module. The null driver (a driver that does nothing) is usually used, but only gets called by pipeman for GetStat/SetStat calls.

A pipe may contain up to 90 bytes, unless a different buffer size was declared. Typically, a pipe is used as a one-way data path between two processes: one writing and one reading. The reader waits for the data to become available and the writer waits for the buffer to empty. However, any number of processes can access the same pipe simultaneously; pipeman coordinates these processes. A process can even arrange for a single pipe to have data sent to itself. You could use this to simplify type conversions by printing data into the pipe and reading it back using a different format.

Data transfer through pipes is extremely efficient and flexible. Data does not have to be read out of the pipe in the same size sections in which it was written.

You can use pipes much like signals to coordinate processes, but with these advantages:

- longer messages (more than 16 bits)
- queued messages
- determination of pending messages
- easy process-independent coordination (using named pipes)

Named and Unnamed Pipes

OS-9 supports both named and unnamed (anonymous) pipes. The shell uses unnamed pipes extensively to construct program “pipelines,” but user programs may use them as well. Unnamed pipes may be opened only once. Independent processes may communicate through them only if the pipeline was constructed by a common parent to the processes. Do this by making each process inherit the pipe path as one of its standard I/O paths.

Named and unnamed pipes function nearly identically. The main difference is that several independent processes may open a named pipe, which simplifies pipeline construction. The sections that follow note other specific differences.

Operations on Pipes

Creating Pipes

The I$Create system call is used with the pipe file manager to create new named or unnamed pipe files.

You may create pipes using the pathlist /pipe (for unnamed pipes, pipe is the name of the pipe device descriptor) or /pipe/<name> (<name> is the logical file name being created). If a pipe file with the same name already exists, an error (E$CEF) is returned. Unnamed pipes cannot return this error.

All processes connected to a particular pipe share the same physical path descriptor. Consequently, the path is automatically set to update mode regardless of the mode specified at creation. You may specify access permissions; they are handled similarly to RBF.

The size of the default FIFO buffer associated with a pipe is specified in the pipe device descriptor. You may override this when creating a pipe by setting the initial file size bit of the mode byte and passing the desired file size in register d2.

If no default or overriding size is specified, a 90-byte FIFO buffer inside the path descriptor is used.

Opening Pipes

When accessing unnamed pipes, I$Open, like I$Create, opens a new anonymous pipe file. When accessing named pipes, I$Open searches for the specified name through a linked list of named pipes associated with a particular pipe device. If I$Open finds the pipe, the path number returned refers to the same physical path allocated when the pipe was created. Internally, this is similar to the I$Dup system call.

Opening an unnamed pipe is simple, but sharing the pipe with another process is more complex. If a new path to /pipe is opened for the second process, the new path is independent of the old one.

The only way for more than one process to share the same unnamed pipe is through the inheritance of the standard I/O paths through the F$Fork call. As an example, the outline on the following page describes a method the shell might use to construct a pipeline for the command dir –u ! qsort. It is assumed that paths 0,1 are already open.

```
StdInp =     I$Dup(0)                    save the shell's standard input
StdOut =     I$Dup(1)                    save shell's standard output
             I$Close(1)                  close standard output
             I$Open("/pipe")             open the pipe (as path 1)
             I$Fork("dir","-u")          fork "dir" with pipe as standard output
             I$Close(0)                  free path 0
             I$Dup(1)                    copy the pipe to path 0
             I$Close(1)                  make path available
             I$Dup(StdOut)               restore original standard out
             I$Fork("qsort")             fork qsort with pipe as standard input
             I$Close(0)                  get rid of the pipe
             I$Dup(StdInp)               restore standard input
             I$Close (StdInp)            close temporary path
             I$Close (StdOut)            close temporary path
```

The main advantage of using named pipes is that several processes may communicate through the same named pipe without having to inherit it from a common parent process. For example, you can approximate the above steps with the following command:

```
dir –u >/pipe/temp & qsort </pipe/temp
```

Important: The OS-9 shell always constructs its pipelines using the unnamed /pipe descriptor.

Read/ReadLn
The I$Read and I$ReadLn system calls return the next bytes in the pipe buffer. If there is not enough data ready to satisfy the request, the process reading the pipe is put to sleep until more data is available.

The end-of-file is recognized when the pipe is empty and the number of processes waiting to read the pipe is equal to the number of users on the pipe. If any data was read before end-of-file was reached, an end-of-file error is not returned. However, the byte count returned is the number of bytes actually transferred, which is less than the number requested.

Important: The Read and Write system calls are faster than ReadLn and WritLn because pipeman does not have to check for carriage returns and the loops moving data are tighter.

Write/WriteLn
The I$Write and I$WritLn system calls work in almost the same way as I$Read and I$ReadLn. A pipe error (E$Write) is returned when all the processes with a full unnamed pipe open are attempting to write to the pipe. Each process attempting to write to the pipe receives the error, and the pipe remains full.

When named pipes are being used, pipeman never returns the E$Write error. If a named pipe gets full before a process that receives data from the pipe opens it, the process writing to the pipe is put to sleep until a process reads the pipe.

Close
When a pipe path is closed, its path count decreases. If no paths are left open on an unnamed pipe, its memory returns to the system. With named pipes, its memory returns only if the pipe is empty. A non-empty pipe (with no open paths) is artificially kept open, waiting for another process to open and read from the pipe. This permits you to use pipes as a type of a temporary, self-destructing RAM disk file.

Getstat/Setstat

Pipeman supports a wide range of status codes, to allow insertion of pipe between processes where a RBF or SCF device would normally be used. For this reason, most RBF and SCF status codes are implemented to do something without returning an error. The actual function may differ slightly from the other file managers, but it is usually compatible.

Getstat Status Codes

Name:	Description:
SS_Opt	Reads the 128 byte option section of the path descriptor. You can use it to obtain the path type, data buffer size, and name of pipe.
SS_Ready	Tests whether data is ready. Returns the number of bytes in the buffer.
SS_Size	Returns the size of the pipe buffer.
SS_EOF	Tests for end-of-file.
SS_FD	Returns a pseudo-file descriptor image.

Other codes are passed to the device driver.

Setstat Status Codes

Name:	Description:
SS_Attr	Changes the pipe file's attributes.
SS_Break	Forces disconnection.
SS_FD	Does nothing, but returns without error.
SS_Opt	Does nothing, but returns without error.
SS_Relea	Releases the device from the SS_SSig processing before data becomes available.
SS_Size	Resets the pipe buffer if the specified size is zero. Otherwise, it has no effect, but returns without error.
SS_SSig	Sends a signal when the data becomes available.

Other codes are passed to the device driver.

The I$MakDir and I$ChgDir service requests are illegal service routines on pipes. They return E$UnkSvc (unknown service request).

Pipe Directories

Opening an unnamed pipe in the Dir mode allows it to be opened for reading. In this case, pipeman allocates a pipe buffer and pre-initializes it to contain the names of all open named pipes on the specified device. Each name is null-padded to make a 32-byte record. This allows utilities, that normally read an RBF directory file sequentially, to work with pipes as well.

Important: Remember that pipeman is not a true directory device, so commands like chd and makdir do not work with /pipe.

The head of a linked list of named pipes is in the static storage of the pipe device driver (usually the null driver). If there are several pipe descriptors with different default pipe buffer sizes on a system, the I/O system notices that the same file manager, device driver, and port address (usually zero) are being used. It will not allocate new static storage for each pipe device and all named pipes will be on the same list.

For example, if two pipe descriptors exist, a directory of either device reveals all the named pipes for both devices. If each pipe descriptor has a unique port address (0,1,...), the I/O system allocates different static storage for each pipe device. This produces more predictable results.

Data Modules

OS-9 data modules enable multiple processes to share a data area and to transfer data among themselves. A **data module** must have a valid CRC and module header to be loaded. A data module can be non-re-entrant; it can modify itself and be modified by several processes.

OS-9 does not have restrictions as to the content, organization, or usage of the data area in a data module. These considerations are determined by the processes using the data module.

OS-9 does not synchronize processes using a data module. Consequently, thoughtful programming, usually involving events or signals, is required to enable several processes to update a shared data module simultaneously.

Creating Data Modules

The F$DatMod system call creates a data module with a specified set of attributes, data area size, and module name. The data area is cleared automatically. The data module is created with a valid CRC and entered into the system module directory.

Important: It is essential that the data module's header and name string not be modified to prevent the module from becoming unknown to the system.

The Microware C compiler provides several C calls to create and use data modules directly. These include the _mkdata_module() call, which is specific to data modules, and the modlink(), modload(), munlink(), and munload() facilities which apply to all OS-9 modules. For more information on these calls, refer to the standard library sections of the OS-9 C Compiler User's Manual.

The Link Count

Like all OS-9 modules, data modules have a link count associated with them. The link count is a counter of how many processes are currently linked to the module. Generally, the module is taken out of memory when this count reaches zero. If you want the module to remain in memory when the link count is zero, when you create the module make it “sticky” by setting the sticky bit in its attribute byte.

Saving to Disk

If a data module is saved to disk, you can use the dump utility to examine the module’s format and contents. You can save a data module to disk using the save utility or by writing the module image into a file. If the data module was modified since its creation, the saved module’s CRC is bad and it is impossible to re-load it into memory. To re-load the module, use the F$SetCRC system call or _setcrc() C library call before writing it to disk. Or, use the fixmod utility after the module has been written to disk.

Chapter 5

User Trap Handlers

Trap Handlers

The 68000 family of microprocessors has sixteen software trap exception vectors. The first (trap 0) is reserved for making OS-9 system calls. You may use the remaining fifteen as service requests to user-defined “user trap handlers.”

Microware provides standard trap handlers for I/O conversions in the C language, floating point math, and trigonometric functions. The following traps are reserved:

Trap:	Description:
trap 13	CIO is automatically called for any C program.
trap 15	Math is called for floating point math, extended integer math and/or type conversion. It is also used for programs using transcendental and/or extended mathematical functions.

For further information about the math module, refer to Chapter 6.

A **user trap handler** is an OS-9 module that usually contains a set of related subroutines. Any user program may dynamically link to the user trap handler and call it at execution time.

Important: While trap handlers reduce the size of the execution program, they do not do anything that could not be done by linking the program with appropriate library routines at compilation time. In fact, programs that call trap handlers execute slightly slower than linked programs that perform the same function.

Trap handlers must be written in a language that compiles to machine code (such as assembly language or C). They should be suitably generic for use by a number of programs.

Trap handlers are similar to normal OS-9 program modules, except that trap handlers have three execution entry points: a trap execution entry point, trap initialization entry point, and trap termination entry point.

Trap handler modules are of module type TrapLib and module language Objct.

The trap module routines usually execute as though they were called with a jsr instruction, except for minor stack differences. Any system calls or other operations that the calling module could perform are usable in the trap module.

It is possible to write a trap handler module that runs in system state. This is rarely advisable, but sometimes necessary. For a discussion of the uses of system state, refer to the System Call Overview in Chapter 2.

Installing and Executing Trap Handlers

A user program installs a trap handler by executing the F$TLink system request. When this is done, the OS-9 kernel links to the trap module, allocates and initializes its static storage (if any), and executes the trap module's initialization routine.

Typically, the initialization routine has very little to do. You could use it to open files, link to additional trap or data modules, or perform other startup activities. It is called only once per trap handler in any given program.

A trap module that is used by a program is usually installed as part of the program's initialization code. At initialization, a particular trap number (1-15) is specified that refers to the trap module. The program invokes functions in the trap module by using the 68000 trap instruction corresponding to the trap number specified. This is followed by a function word that is passed to the trap handler itself. The arrangement is very similar to making a normal OS-9 system call.

The OS-9 relocatable macro assembler has special mnemonics to make trap calls more apparent. These are OS9 for trap 0, and tcall for the other user traps. They work like built-in macros, generating code as illustrated in the following section.

OS-9 and tcall: Equivalent Assembly Language Syntax

Mnemonic:	Code generated:
OS9 F$TLink	trap 0 dc.w F$TLink
tcall T$Math,T$DMul	trap T$Math dc.w T$DMul

From user programs, it is possible to delay installing a trap module until the first time it is actually needed. If a trap module has not been installed for a particular trap when the first tcall is made, OS-9 checks the program's exception entry offset (M$Excpt in the module header). The program aborts if this offset is zero. Otherwise, OS-9 passes control to the exception routine. At this point, the trap handler can be installed, and the first tcall reissued. The second example in this chapter shows how to do this.

Calling a Trap Handler

The actual details of building and using a trap handler are best explained by means of a simple complete example.

Example One:
The following program (TrapTst) uses trap vector 5. It installs the trap handler and then calls it twice.

```
            nam    TrapTst1
            ttl    example one – link and call trap handler
            use    /dd/defs/oskdefs.d
Edition     equ    1
Typ_Lang    equ    (Prgrm<<8)+Objct
Attr_Rev    equ    (ReEnt<<8)+0
            psect
traptst,Typ_Lang,Attr_Rev,Edition,1024,Test

TrapNum     equ    5              trap number to use
TrapName    dc.b   "trap",0       name of trap handler

*****************************

* Main program entry point
Test:       moveq  #TrapNum,d0          trap number to assign
            moveq  #0,d1             no optional memory override
            lea    TrapName(pc),a0   ptr to name of trap handler
            os9    F$TLink                 install trap handler
            bcs.s  Test99                       abort if error
            tcall  TrapNum,0             call trap function #0
            bcs.s  Test99                       abort if error
            tcall  TrapNum,1             call trap function #1
            bcs.s  Test99                       abort if error
            moveq  #0,d1                 exit without error
Test99      os9    F$Exit                                exit
            ends
```

Example Two:
The following example shows how you could modify the preceding program to install the trap handler in an exception routine when the first tcall is executed. You might do this for a trap handler that may not be used at all by a program, depending on circumstances.

This example does not initialize the trap handler before using it, but is otherwise identical to Example One. It provides a LinkTrap subroutine to automatically install the trap handler when it is first used. Refer to the trace of Example Two later in this chapter for more information.

```
            nam     TrapTst2
            ttl     example two – call trap handler
            use     /dd/defs/oskdefs.d
Edition     equ     1
Typ_Lang    equ     (Prgrm<<8)+Objct
Attr_Rev    equ     (ReEnt<<8)+0
            psect
traptst,Typ_Lang,Attr_Rev,Edition,1024,Test,LinkTrap
TrapNum     equ     5                              trap number to use
TrapName    dc.b    “trap”,0                       name of trap handler

*********************************

* Main program entry point
Test:       tcall   TrapNum,0                      call trap function #0
            bcs.s   Test99                           abort if error
            tcall   TrapNum,1                      call trap function #1
            bcs.s   Test99                           abort if error
            moveq   #0,d1                          exit without error
Test99      os9     F$Exit                                   exit

*********************************

* Subroutine LinkTrap
* Installs trap handler and then executes first trap call.
* Note:  Error checking is minimized to keep example simple.
*
* Passed:  d0–d7 = caller’s registers
*          a0–a5 = caller’s registers
*          (a6)  = trap handler static storage pointer
*          (a7)  = trap init/entry stack frame
*
* Returns: trap installed, backs up PC to execute “tcall” instruction
*
* The stack looks like this:
*           .------------------------.
*       +8 |   caller’s return PC   |
*          >------------------------<
*       +6 |  vector #  |
*          >------------<
*       +4 | func code  |
*          >------------------------<
*          |  caller’s a6 register  |
*    (a7)-> ------------------------

LinkTrap:   addq.l  #8,a7                      discard excess stack info
            movem.l d0–d1/a0–a2,–(a7)                save registers
            moveq   #TrapNum,d0                trap number to assign
            moveq   #0,d1                    no optional memory override
            lea     TrapName(pc),a0            ptr to name of trap handler
            os9     F$TLink                        install trap handler
            bcs.s   Test99                           abort if error
            movem.l (a7)+,d0–d1/a0–a2              retrieve registers
            subq.l  #4,(a7)                  back up to tcall instruction
            rts     return                           to tcall instruction
            ends
```

An Example Trap Handler

The following makefile makes the example trap handler and test programs:

```
# makefile – Used to make the example trap handler and test
programs.
RDIR   = RELS
TRAP   = trap
TEST1  = traptst1
TEST2  = traptst2

# Dependencies for making the entire trap example.

trap.example: $(TRAP) $(TEST1) $(TEST2)
    touch trap.example

# Dependencies for making the trap handler.

$(TRAP): $(TRAP).r
    l68 –g $(RDIR)/$(TRAP).r –l=/dd/lib/sys.l –o=$(TRAP)

# Dependencies for making the traptst1 test program.

$(TEST1): $(TEST1).r
    l68 –g $(RDIR)/$(TEST1).r –l=/dd/lib/sys.l –o=$(TEST1)

# Dependencies for making the traptst2 test program.

$(TEST2): $(TEST2).r
    l68 –g $(RDIR)/$(TEST2).r –l=/dd/lib/sys.l –o=$(TEST2)
```

The trap handler itself is listed below. It is artificially simple to avoid confusion. Most trap handlers have several functions, and generally begin with a dispatch routine based on the function code.

```
          nam     Trap Handler
          ttl     Example trap handler module
          use     /dd/defs/oskdefs.d
Type      set     (TrapLib<<8)+Objct
Revs      set     ReEnt<<8
          psect   traphand,Type,Revs,0,0,TrapEnt
          dc.l    TrapInit                    initialization entry point
          dc.l    TrapTerm                     termination entry point

**************************************************
* TrapInit:  Trap handler initialization entry point.
*
* Passed:  d0.w  = User Trap number (1–15)
*          d1.l  = (optional) additional static storage
*          d2–d7 = caller’s registers at the time of the trap
*          (a0)  = trap handler module name pointer
*          (a1)  = trap handler execution entry point
*          (a2)  = trap module pointer
*          a3–a5 = caller’s registers (parameters required by
handler)
*          (a6)  = trap handler static storage pointer
*          (a7)  = trap init stack frame pointer
*
* Returns: (a0)  = updated trap handler name pointer
*          (a1)  = trap handler execution entry point
*          (a2)  = trap module pointer
*          cc    = carry set, d1.w=error code if error
*          Other values returned are dependent on the trap handler
*
* The stack looks like this:
*          .-------------------------.
*       +8 |    caller’s return PC   |
*          >-------------------------<
*       +4 |    0000    |    0000    |
*          >------------|------------<
*          |   caller’s a6 register  |
*    (a7)-> -------------------------
TrapInit  movem.l (a7),a6                restore user’s a6 register
          addq.l  #8,a7                 take other stuff off the stack
          rts                                    return to caller

****************************************
* TrapEnt:  User trap handler entry point.
*
* Passed:  d0–d7 = caller’s registers
*          a0–a5 = caller’s registers
*          (a6)  = trap handler’s static storage pointer
*          (a7)  = trap entry stack frame pointer
*
* Returns: cc    = carry set, d1.w=error code if error
*          Other values returned are dependent on the trap handler
*
```

Example Trap Handler Continued

```
* The stack looks like this:
*          .------------------------.
*       +8 |   caller's return PC   |
*          >------------------------<
*       +6 |  vector #  |
*          >------------<
*       +4 | func code  |
*          >------------------------<
*          |  caller's a6 register  |
*    (a7)-> ------------------------
```

```
          org     0                              stack offset definitions
S.d0      do.l    1                                   caller's d0 reg
S.d1      do.l    1                                   caller's d1 reg
S.a0      do.l    1                                   caller's a0 reg
S.a6      do.l    1                                   caller's a6 reg
S.func    do.w    1                                 trap function code
S.vect    do.w    1                                   vector number
S.pc      do.l    1                                      return pc

TrapEnt:  movem.l d0-d1/a0,-(a7)                      save registers
          move.w  S.func(a7),d0                     get function code
          cmp.w   #1,d0                          is function in range?
          bhi.s   FuncErr                                abort if not
          beq.s   Trap10                      branch if function code #1
          lea     String1(pc),a0                  get first string ptr
          bra.s   Trap20                                    continue
Trap10    lea     String2(pc),a0                 get second string ptr
Trap20    moveq   #1,d0                          standard output path
          moveq   #80,d1                      maximum bytes to write
          os9     I$WritLn                          output the string
          bcs.s   Abort                                 abort if error
Trap90    movem.l (a7)+,d0-d1/a0/a6-a7                   restore regs
          rts                                          return to user

FuncErr   move.w  #1<<8+99,d2              abort (return error 001:099)
Abort     move.w  d1,S.d1+2(a7)                 put error code in d1.w
          ori     #Carry,ccr                              set carry
          bra.s   Trap90                                       exit

String1   dc.b    "Microware Systems Corporation",C$CR,0
String2   dc.b    "    Quality keeps us #1",C$CR,0

********************************************
* TrapTerm:  Trap handler terminate entry point.
*
* As of this release (OS-9 V2.4) the trap termination entry
* point is never called by the OS-9 kernel.  Documentation
* details will be available when a working implementation
* exists.

TrapTerm  move.w  #1<<8+199,d1                never called, if it gets here
          os9     F$Exit                  crash program (Error 001:199)
          ends
```

Trace of Example Two Using the Example Trap Handler

It is extremely educational to watch the OS-9 user debugger trace through the execution of Example Two (using the example trap handler). User trap handlers look like subroutines to the debugger, so it is possible to trace through them. The output should appear something like this:

```
(beginning of second example program)
Test                >4E450000         trap #5,0
```

Important: Because the trap handler has not been linked as in Example One, control jumps to the subroutine LinkTrap:

```
LinkTrap            >508F             addq.l #8,a7
LinkTrap+0x2        >48E7C0E0         movem.l d0–d1/a0–a2,–(a7)
LinkTrap+0x6        >7005             moveq.l #5,d0
LinkTrap+0x8        >7200             moveq.l #0,d1
LinkTrap+0xA        >41FAFFDC         lea.l bname+0xA(pc),a0
LinkTrap+0xE        >4E400021         os9 F$TLink
```

Important: Control switches to the subroutine TrapInit and then returns to LinkTrap:

```
trap:btext+0x50     >4CD74000         movem.l (a7),a6
trap:btext+0x54     >508F             addq.l #8,a7
trap:btext+0x56     >4E75             rts
LinkTrap+0x12       >65E8             bcs.b Test+0xE
LinkTrap+0x14       >4CDF0703         movem.l (a7)+,d0–d1/a0–a2
LinkTrap+0x18       >5997             subq.l #4,(a7)
LinkTrap+0x1A       >4E75             rts
```

Important: Control now returns to the main program to re-execute the tcall instruction.

```
Test                >4E450000         trap #5,0
trap:TrapEnt        >48E7C080         movem.l d0–d1/a0,–(a7)
trap:TrapEnt+0x4    >302F0010         move.w 16(a7),d0
trap:TrapEnt+0x8    >B07C0001         cmp.w #1,d0
trap:TrapEnt+0xC    >621C             bhi.b trap:TrapEnt+0x2A
trap:TrapEnt+0xE    >6706             beq.b trap:TrapEnt+0x16
trap:TrapEnt+0x10   >41FA0026         lea.l trap:TrapEnt+0x38(pc),a0
trap:TrapEnt+0x14   >6004             bra.b trap:TrapEnt+0x1A
trap:TrapEnt+0x1A   >7001             moveq.l #1,d0
trap:TrapEnt+0x1C   >7250             moveq.l #80,d1
trap:TrapEnt+0x1E   >4E40008C         os9 I$WritLn
Microware Systems Corporation
trap:TrapEnt+0x22   >650A             bcs.b trap:TrapEnt+0x2E
trap:TrapEnt+0x24   >4CDFC103         movem.l (a7)+,d0–d1/a0/a6–a7
trap:TrapEnt+0x28   >4E75             rts
Test+0x4            >6508             bcs.b Test+0xE
Test+0x6            >4E450001         trap #5,0x1

trap:TrapEnt        >48E7C080         movem.l d0–d1/a0,–(a7)
trap:TrapEnt+0x4    >302F0010         move.w 16(a7),d0
trap:TrapEnt+0x8    >B07C0001         cmp.w #1,d0
trap:TrapEnt+0xC    >621C             bhi.b trap:TrapEnt+0x2A
trap:TrapEnt+0xE    >6706             beq.b trap:TrapEnt+0x16–>
trap:TrapEnt+0x16   >41FA003F         lea.l trap:TrapEnt+0x57(pc),a0
trap:TrapEnt+0x1A   >7001             moveq.l #1,d0
trap:TrapEnt+0x1C   >7250             moveq.l #80,d1
trap:TrapEnt+0x1E   >4E40008C         os9 I$WritLn
    Quality keeps us #1
trap:TrapEnt+0x22   >650A             bcs.b trap:TrapEnt+0x2E
trap:TrapEnt+0x24   >4CDFC103         movem.l (a7)+,d0–d1/a0/a6–a7
trap:TrapEnt+0x28   >4E75             rts
Test+0xA            >6502             bcs.b Test+0xE
Test+0xC            >7200             moveq.l #0,d1
Test+0xE            >4E400006         os9 F$Exit
```

Chapter 6

The Math Module

The Standard Function Library Module

OS-9 contains a standard function library math module which provides common subroutines for extended mathematical and I/O conversion functions. OS-9 C, Basic09, and Fortran compilers also use this module.

OS-9 math modules provide the following functions:

- basic floating point math
- extended integer math
- type conversion
- transcendental and extended mathematical functions

Normally, the math module uses software routines located in a library file to provide the extended functions. User programs can call the library directly, using the 68000 trap instruction. You can also use these library files for non-OS-9 target systems. The following are library files that can be embedded in your applications:

Library File	Use on:
Math.l	Systems without a math co-processor.
Math881.l	Systems with a math co-processor.

Systems that do not use a math co-processor can use the Math.l library file. In systems that do have a math co-processer, you can replace the software-based files with files that use arithmetic processing hardware, without altering the application software. For example, use the Math881 file for the 68881/882 FPCP.

If you do not want the math module functions embedded within your application program, you can install the appropriate module as a user trap routine, and call it using the 68000 trap instruction.

Module name:	File name:	Trap#	Use on:
Math	Math	15	Systems without a math co-processor.
Math	Math881	15	Systems with a math co-processor.

Calling Standard Function Module Routines

You can use the OS-9 Load command to pre-load the standard function library module in memory for quick access when needed. You can make it part of the system's startup file. Including the trap handlers in the OS9Boot file is not recommended. The following description of standard function module linkage and calling methods is intended for assembly language programmers. Programs generated by the OS-9 compilers automatically perform all required functions without any special action on the part of the user.

Prior to calling the standard function modules, an assembly language program should use the OS-9 F$TLink system call. The TLink parameters should be the trap number and module name (refer to the table on the previous page). This installs and links the user's process to the desired module(s). Calls to individual routines are made using the trap instruction. For example, a call to the FAdd function could look like this:

```
trap    #T$Math         Trap number of module
dc.w    T$FAdd          Code of FAdd function
```

For simplicity, a macro is included in the assembler for this purpose. The following line is equivalent to the above example:

```
tcall   T$Math,T$FAdd  Trap number and code for FAdd
```

In non-OS-9 target environments, you may also call these routines directly using bsr instructions, and including the appropriate library in the code (math.l). For example:

```
bsr     _T$FAdd         Floating point addition
```

Many functions set the MPU status register N, Z, V, and C bits so the trap or bsr may be immediately followed by a conditional branch instruction for comparisons and error checking. When an error occurs, the system-wide convention is followed, where the C condition code bit is set and register d1 returns the specific error code.

In some cases a trapv instruction executes at the end of a function. This causes a trapv exception if the V (overflow) condition code is set.

Data Formats

Some functions support two integer types:

```
unsigned       32-bit unsigned integers
long           32-bit signed integers
```

Two floating point formats are also supported:

```
float          32-bit floating point numbers
double         64-bit double precision floating point
numbers
```

Floating point math routines use formats based on the proposed IEEE standard for compatibility with floating point math hardware. 32-bit floating point operands are internally converted to 64-bit double precision before computation and converted back to 32 bits afterwards as required by the IEEE and C language standards. Therefore, the float type has no speed advantage over the double type. This package does not support de-normalized numbers and negative zero.

The Math Module

The math module provides single and double precision floating point arithmetic, extended integer arithmetic, and type conversion routines.

Integer Operations

```
T$LMul    T$UMul    T$LDiv    T$LMod    T$UDiv    T$UMod
```

Single Precision Floating Point Operations

```
T$FAdd    T$FInc    T$FSub    T$FDec    T$FMul    T$FDiv    T$FCmp    T$FNeg
```

Double Precision Floating Point Operations

```
T$DAdd    T$DInc    T$DSub    T$DDec    T$DMul    T$DDiv    T$DCmp     T$DNeg
```

ASCII to Numeric Conversions

```
T$AtoN    T$AtoL    T$AtoU    T$AtoF    T$AtoD
```

Numeric to ASCII Conversions

```
T$LtoA    T$UtoA    T$FtoA    T$DtoA
```

Numeric to Numeric Conversions

```
T$LtoF    T$LtoD    T$UtoF    T$UtoD    T$FtoL    T$DtoL    T$FtoU     T$DtoU
T$FtoD    T$DtoF    T$FTrn    T$DTrn    T$FInt    T$DInt    T$DNrm
```

The math module also provides transcendental and extended mathematical functions. The calling routine controls the precision of these routines. For example, if fourteen digits of precision are required, the floating-point representation for 1E-014 should be passed to the routine.

Function name:	Operation:
T$Sin	Sine function
T$Cos	Cosine function
T$Tan	Tangent function
T$Asn	Arc sine function
T$Acs	Arc cosine function
T$Atn	Arc tangent function
T$Log	Natural logarithm function
T$Log10	Common logarithm function
T$Sqrt	Square root function
T$Exp	Exponential function
T$Power	Power function

The following table contains the hex representations which you should pass to these routines to define the precision of the operation.

Precision hex:	Representation:
1E–001	3fb99999 9999999a
1E–002	3f847ae1 47ae147b
1E–003	3f50624d d2f1a9fc
1E–004	3f1a36e2 eb1c432d
1E–005	3ee4f8b5 88e368f1
1E–006	3eb0c6f7 a0b5ed8e
1E–007	3e7ad7f2 9abcaf4a
1E–008	3e45798e e2308c3b
1E–009	3e112e0b e826d696
1E–010	3ddb7cdf d9d7bdbd
1E–011	3da5fd7f e1796497
1E–012	3d719799 812dea12
1E–013	3d3c25c2 68497683
1E–014	3d06849b 86a12b9c

Important: Using a precision greater than 14 digits may cause the routine to get trapped in an infinite loop.

T$Acs

Arc Cosine Function

ASM Call

```
TCALL T$Math,T$Acs
```

Input

```
d0:d1 = x
d2:d3 = Precision
```

Output

```
d0:d1 = ArcCos(x) (in radians)
```

Condition Codes

```
C  Set on error
```

Possible Errors

```
E$IllArg
```

Function

`T$Acs` returns the arc cosine() in radians. If the operand passed is illegal, an error is returned.

T$Asn

Arcsine Function

ASM Call

```
TCALL T$Math,T$Asn
```

Input

```
d0:d1 = x
d2:d3 = Precision
```

Output

```
d0:d1 = ArcSin(x) (in radians)
```

Condition Codes

```
C  Set on error
```

Possible Errors

```
E$IllArg
```

Function

`T$Asn` returns the arcsine() in radians. If the operand passed is illegal, an error is returned.

T$Atn

Arc Tangent Function

ASM Call

```
TCALL T$Math,T$Atn
```

Input

```
d0:d1 = x
d2:d3 = Precision
```

Output

```
d0:d1 = ArcTan(x) (in radians)
```

Condition Codes

```
C  Set on error
```

Possible Errors

```
E$IllArg
```

Function

`T$Atn` returns the arc tangent() in radians. If the operand passed is illegal, an error is returned.

T$AtoD

ASCII to Double-Precision Floating-Point

ASM Call

```
TCALL T$Math,T$AtoD
```

Input

```
(a0) = Pointer to ASCII string
       Format: <sign><digits>.<digits><E or e><sign><digits>
```

Output

```
(a0) = Updated pointer
d0:d1 = Double-precision floating-point number
```

Condition Codes

```
N  Undefined
Z  Undefined
V  Set on underflow or overflow
C  Set on error
```

Possible Errors

`E$NotNum` or `E$FmtErr`

Function

`T$AtoD` performs a conversion from an ASCII string to a double-precision floating-point number. If the first character is not the sign (+ or) or a digit, E$NotNum is returned. If the first character following the E is not the sign or a digit, E$FmtErr is returned.

If the overflow bit (V) is set, zero (on underflow) or +/– infinity (overflow) is returned.

T$AtoF

ASCII to Single-Precision Floating-Point

ASM Call

```
TCALL T$Math,T$AtoF
```

Input

```
(a0) = Pointer to ASCII string
       Format: <sign><digits>.<digits><E or e><sign><digits>
```

Output

```
(a0) = Updated pointer
d0:d1 = Double-precision floating-point number
```

Condition Codes

```
N  Undefined
Z  Undefined
V  Set on underflow or overflow
C  Set on error
```

Possible Errors

`E$NotNum` or `E$FmtErr`

Function

`T$AtoF` performs a conversion from an ASCII string to a single-precision floating-point number. If the first character is not the sign (+ or –) or a digit, E$NotNum is returned. If the first character following the E is not the sign or a digit, E$FmtErr is returned.

If the overflow bit (V) is set, zero (on underflow) or +/– infinity (overflow) is returned.

T$AtoL

ASCII to Long Conversion

ASM Call

```
TCALL T$Math,T$AtoL
```

Input

```
(a0) = Pointer to ASCII string (format: <sign><digits> )
```

Output

```
(a0) = Updated pointer
d0.l = Signed long
```

Condition Codes

```
N  Undefined
Z  Undefined
V  Set on overflow
C  Set on error
```

Possible Errors

```
E$NotNum
```

Function

`T$AtoL` performs a conversion from an ASCII string to a signed long integer. If the first character is not a sign (+ or –) or a digit, an error is returned.

T$AtoN

ASCII to Numeric Conversion

ASM Call

```
TCALL T$Math,T$AtoN
```

Input

```
(a0) = Pointer to ASCII string
```

Output

```
(a0) = Updated pointer
d0 = Number if returned as long (signed or unsigned)
d0:d1 = Number if returned in floating point format
```

Condition Codes

See explanation below.

Possible Errors

```
TrapV
```

Function

`T$AtoN` can return results of various types depending on the format of the input string and the magnitude of the converted value. The type of the result is passed back to the calling program using the V and N condition code bits.

V=0 and N=1 indicate a signed integer is returned in d0.l
V=0 and N=0 indicate an unsigned integer is returned in d0.l
V=1 indicates a double-precision number is returned in d0:d1

If any of the following conditions are met, the number is returned as a double-precision floating-point value:

- The number is positive and overflows an unsigned long.
- The number is negative and overflows a signed long.
- The number contains a decimal point and/or an E exponent.

If none of the above conditions are met, the result is returned as an unsigned long (if positive) or a signed long (if negative).

T$AtoU

ASCII to Unsigned Conversion

ASM Call

```
TCALL T$Math,T$AtoU
```

Input

```
(a0) = Pointer to ASCII string (format: <digits >)
```

Output

```
(a0) = Updated pointer
d0.l = Unsigned long
```

Condition Codes

```
N  Undefined
Z  Undefined
V  Set on overflow
C  Set on error
```

Possible Errors

```
E$NotNum
```

Function

`T$AtoU` performs a conversion from an ASCII string to an unsigned long integer. If the first character is not a digit, an error is returned.

T$Cos

Cosine Function

ASM Call

```
TCALL T$Math,T$Cos
```

Input

```
d0:d1 = x (in radians)
d2:d3 = Precision
```

Output

```
d0:d1 = Cos(x)
```

Condition Codes

```
C  Always clear
```

Possible Errors

None

Function

`T$Cos` returns the cosine() of an angle. The angle must be specified in radians. No errors are possible, and all condition codes are undefined.

T$DAdd

Double Precision Addition

ASM Call

```
TCALL T$Math,T$DAdd
```

Input

```
d0:d1 = Addend
d2:d3 = Augend
```

Output

```
d0:d1 = Result  ( d0:d1 + d2:d3 )
```

Condition Codes

```
N  Set if result is negative
Z  Set if result is zero
V  Set on underflow or overflow
C  Always cleared
```

Possible Errors

```
TrapV
```

Function

`T$DAdd` adds two double-precision floating point numbers. Overflow and underflow are indicated by setting the V bit. In either case, a trapv exception is generated. If an underflow caused the exception, zero is returned. If it was an overflow, infinity (with the proper sign) is returned.

T$DCmp

Double Precision Compare

ASM Call

```
TCALL T$Math,T$DCmp
```

Input

```
d0:d1 = First operand
d2:d3 = Second operand
```

Output

```
d0.l through d3.l remain unchanged
```

Condition Codes

```
N  Set if second operand is larger than the first
Z  Set if operands are equal
V  Always cleared
C  Always cleared
```

Possible Errors

None

Function

Two double-precision floating point numbers are compared by T$DCmp. The operands passed to this function are not destroyed.

T$DDec

Double Precision Decrement

ASM Call

```
TCALL T$Math,T$DDec
```

Input

```
d0:d1 = Operand
```

Output

```
d0:d1 = Result  ( d0:d1 – 1.0 )
```

Condition Codes

```
N  Set if result is negative
Z  Set if result is zero
V  Set on underflow
C  Always cleared
```

Possible Errors

```
TrapV
```

Function

This function subtracts 1.0 from the double-precision floating point operand. Underflow is indicated by setting the V bit. If an underflow occurs, a trapv exception is generated and zero is returned.

T$DDiv

Double Precision Divide

ASM Call

```
TCALL T$Math,T$DDiv
```

Input

```
d0:d1 = Dividend
d2:d3 = Divisor
```

Output

```
d0:d1 = Result  ( d0:d1 / d2:d3 )
```

Condition Codes

```
N  Set if result is negative
Z  Set if result is zero
V  Set on underflow, overflow, or divide by zero
C  Set on divide by zero
```

Possible Errors

```
TrapV
```

Function

`T$DDiv` performs division on two double-precision floating point numbers. Overflow, underflow, and divide-by-zero are indicated by setting the V bit. In any case, a trapv exception is generated. If an underflow caused the exception, zero is returned. If it was an overflow or divide-by-zero, infinity (with the proper sign) is returned.

T$DInc

Double Precision Increment

ASM Call

```
TCALL T$Math,T$DInc
```

Input

```
d0:d1 = Operand
```

Output

```
d0:d1 = Result  ( d0:d1 + 1.0 )
```

Condition Codes

```
N  Set if result is negative
Z  Set if result is zero
V  Set on overflow
C  Always cleared
```

Possible Errors

```
TrapV
```

Function

`T$DInc` adds 1.0 to the double-precision floating point operand. Overflow is indicated by setting the V bit. If an overflow occurs, a trapv exception is generated and infinity (with the proper sign) is returned.

T$DInt

Round Double-Precision Floating-Point Number

ASM Call

```
TCALL T$Math,T$DInt
```

Input

```
d0:d1 = Double-precision floating-point number
```

Output

```
d0:d1 = Rounded double-precision floating-point number
```

Condition Codes

```
All condition codes are undefined.
```

Possible Errors

None

Function

Floating point numbers consist of two parts: integer and fraction. The purpose of T$DInt is to round the floating point number passed to it, leaving only an integer. If the fraction is exactly 0.5, the integer is rounded to an even number.

Examples

23.45 rounds to 23.00
23.50 rounds to 24.00
23.73 rounds to 24.00
24.50 rounds to 24.00 (rounds to even number)

T$DMul

Double Precision Multiplication

ASM Call

```
TCALL T$Math,T$DMul
```

Input

```
d0:d1 = Multiplicand
d2:d3 = Multiplier
```

Output

```
d0:d1 = Result  ( d0:d1 * d2:d3 )
```

Condition Codes

```
N  Set if result is negative
Z  Set if result is zero
V  Set on underflow or overflow
C  Always cleared
```

Possible Errors

```
TrapV
```

Function

`T$DMul` multiplies two double-precision floating point numbers. Overflow and underflow are indicated by setting the V bit. In either case, a trapv exception is generated. If an underflow caused the exception, zero is returned. If it was an overflow, infinity (with the proper sign) is returned.

T$DNeg

Double Precision Negate

ASM Call

```
TCALL T$Math,T$DNeg
```

Input

```
d0:d1 = Operand
```

Output

```
d0:d1 = Result  ( d0:d1 * –1.0 )
```

Condition Codes

```
N  Set if result is negative
Z  Set if result is zero
V  Always cleared
C  Always cleared
```

Possible Errors

None

Function

`T$DNeg` negates a double-precision floating point operand. To eliminate the overhead of calling this routine, it is simple to change the sign bit of the floating-point number. However, you should check for a zero number because this package does not support negative zero.

This example is written as a subroutine and expects the floating-point number to be in d0:d1.

```
Negate  tst.l d0     test for zero
        beq.s Neg10  branch if it is zero
        bchg  #31,d0 change sign bit
Neg10   rts          return
```

T$DNrm

64-bit Unsigned to Double-Precision Conversion

ASM Call

```
TCALL T$Math,T$DNrm
```

Input

```
d0:d1 = 64-bit Unsigned Integer
d2.l = Exponent
```

Output

```
d0:d1 = Double-precision floating-point number
```

Condition Codes

```
N  Undefined
Z  Undefined
V  Set on underflow or overflow
C  Undefined
```

Possible Errors

None

Function

Double-precision floating point numbers maintain 52 bits of mantissa. `T$DNrm` converts a 64-bit binary number to double-precision format. The extra 12 bits are rounded. If an underflow or overflow occurs, the V bit is set, but a trapv exception is not generated.

T$DSub

Double-Precision Subtraction

ASM Call

```
TCALL T$Math,T$DSub
```

Input

```
d0:d1 = Minuend
d2:d3 = Subtrahend
```

Output

```
d0:d1 = Result  ( d0:d1 – d2:d3 )
```

Condition Codes

```
N  Set if result is negative
Z  Set if result is zero
V  Set on underflow or overflow
C  Always cleared
```

Possible Errors

```
TrapV
```

Function

T$DSub performs subtraction on two double-precision floating point numbers. Overflow and underflow are indicated by setting the V bit. In either case, a trapv exception is generated. If an underflow caused the exception, zero is returned. If it was an overflow, infinity (with the proper sign) is returned.

T$DtoA

Double-Precision Floating-Point to ASCII

ASM Call

```
TCALL T$Math,T$DtoA
```

Input

```
d0:d1 = Double-precision floating-point number
d2.l = Low-Word: digits desired in result
       High-Word: digits desired after decimal-point
(a0) = Pointer to conversion buffer
```

Output

```
(a0) = ASCII digit string
d0.l = Two’s complement exponent
```

Condition Codes

```
N  Set if the number is negative
Z  Undefined
V  Undefined
C  Undefined
```

Possible Errors

None

Function

The double-precision float passed to T$DtoA is converted to an ASCII string. The conversion terminates as soon as the number of digits requested are converted, or when the specified digit after the decimal point is reached; whichever comes first. A null is appended to the end of the string. Therefore, the buffer should be one byte larger than the expected number of digits.

The converted string only contains the mantissa digits. The N bit indicates the sign of the number, and the exponent returns in register d0.

T$DtoF

Double to Single Floating-Point Conversion

ASM Call

```
TCALL T$Math,T$DtoF
```

Input

```
d0:d1 = Double-precision floating-point number
```

Output

```
d0.l = Single-precision floating-point number
```

Condition Codes

```
N  Undefined
Z  Undefined
V  Set on underflow or overflow
C  Undefined
```

Possible Errors

```
TrapV
```

Function

`T$DtoF` converts floating-point numbers in double-precision format to single-precision format. No errors are possible and all condition codes are undefined. If an overflow or underflow occurs, the V bit is set and a trapv exception is generated.

T$DtoL

Double-Precision to Signed Long Integer

ASM Call

```
TCALL T$Math,T$DtoL
```

Input

```
d0:d1 = Double-precision floating-point number
```

Output

```
d0.l = Signed Long Integer
```

Condition Codes

```
N  Undefined
Z  Undefined
V  Set on overflow
C  Undefined
```

Possible Errors

```
TrapV
```

Function

The integer portion of the floating point number is converted to a signed long integer. The fraction is truncated. If an overflow occurs, the V bit is set and a trapv exception is generated.

T$DtoU

Double-Precision to Unsigned Long Integer

ASM Call

```
TCALL T$Math,T$DtoU
```

Input

```
d0:d1 = Double-precision floating-point number
```

Output

```
d0.l = Unsigned Long Integer
```

Condition Codes

```
N  Undefined
Z  Undefined
V  Set on overflow
C  Undefined
```

Possible Errors

```
TrapV
```

Function

The integer portion of the floating point number converts to an unsigned long integer. The fraction is truncated. If an overflow occurs, the V bit is set and a trapv exception is generated.

T$DTrn

Truncate Double-Precision Floating-Point Number

ASM Call

```
TCALL T$Math,T$DTrn
```

Input

```
d0:d1 = Double-precision floating-point number
```

Output

```
d0:d1 = Normalized integer portion of the floating point
number
d2:d3 = Normalized fractional portion of the floating point
number
```

Condition Codes

All condition codes are undefined.

Possible Errors

None

Function

Floating point numbers consist of two parts: integer and fraction. The purpose of T$DTrn is to separate the two parts. For example, if the number passed is 283.75, this function returns 283.00 in d0:d1 and 0.75 in d2:d3.

T$Exp

Exponential Function

ASM Call

```
TCALL T$Math,T$Exp
```

Input

```
d0:d1 = x
d2:d3 = Precision
```

Output

```
d0:d1 = Exp(x)
```

Condition Codes

```
C  Always clear
```

Possible Errors

None

Function

`T$Exp` performs the exponential function on the argument passed. That is, it raises e to the x power (where e = 2.718282 and x is the argument passed).

T$FAdd

Single Precision Addition

ASM Call

```
TCALL T$Math,T$FAdd
```

Input

```
d0.l = Addend
d0.l = Augend
```

Output

```
d0.l = Result  ( d0 + d1 )
```

Condition Codes

```
N  Set if result is negative
Z  Set if result is zero
V  Set on underflow or overflow
C  Always cleared
```

Possible Errors

```
TrapV
```

Function

`T$FAdd` adds two single-precision floating point numbers. Overflow and underflow are indicated by setting the V bit. In either case, a trapv exception is generated. If an underflow caused the exception, zero is returned. If it was an overflow, infinity (with the proper sign) is returned.

T$FCmp

Single Precision Compare

ASM Call

```
TCALL T$Math,T$FCmp
```

Input

```
d0.l = First operand
d1.l = Second operand
```

Output

```
d0.l and d1.l remain unchanged
```

Condition Codes

```
N  Set if second operand is larger than the first
Z  Set if operands are equal
V  Always cleared
C  Always cleared
```

Possible Errors

None

Function

Two single-precision floating point numbers are compared by T$FCmp. The operands passed to T$FCmp are not destroyed.

T$FDec

Single Precision Decrement

ASM Call

```
TCALL T$Math,T$FDec
```

Input

```
d0.l = Operand
```

Output

```
d0.l = Result  ( d0 – 1.0 )
```

Condition Codes

```
N  Set if result is negative
Z  Set if result is zero
V  Set on underflow
C  Always cleared
```

Possible Errors

```
TrapV
```

Function

`T$FDec` subtracts 1.0 from the single-precision floating point operand. Underflow is indicated by setting the V bit. If an underflow occurs, a trapv exception is generated and zero is returned.

T$FDiv

Single Precision Divide

ASM Call

```
TCALL T$Math,T$FDiv
```

Input

```
d0.l = Dividend
d1.l = Divisor
```

Output

```
d0.l = Result  ( d0 / d1 )
```

Condition Codes

```
N  Set if result is negative
Z  Set if result is zero
V  Set on underflow, overflow or divide by zero
C  Set on divide by zero
```

Possible Errors

```
TrapV
```

Function

`T$FDiv` performs division on two single-precision floating point numbers. Overflow, underflow, and divide-by-zero are indicated by setting the V bit. In any case, a trapv exception is generated. If an underflow caused the exception, zero is returned. If it was an overflow or divide-by-zero, infinity (with the proper sign) is returned.

T$FInc

Single Precision Increment

ASM Call

```
TCALL T$Math,T$FInc
```

Input

```
d0.l = Operand
```

Output

```
d0.l = Result  ( d0 + 1.0 )
```

Condition Codes

```
N  Set if result is negative
Z  Set if result is zero
V  Set on overflow
C  Always cleared
```

Possible Errors

```
TrapV
```

Function

`T$FInc` adds 1.0 to the single-precision floating point operand. Overflow is indicated by setting the V bit. If an overflow occurs, a trapv exception is generated and infinity (with the proper sign) is returned.

T$FInt

Round Single-Precision Floating-Point Number

ASM Call

```
TCALL T$Math,T$FInt
```

Input

```
d0.l = Single-precision floating-point number
```

Output

```
d0.l = Rounded single-precision floating-point number
```

Condition Codes

```
All condition codes are undefined.
```

Possible Errors

None

Function

Floating point numbers consist of two parts: integer and fraction. The purpose of T$FInt is to round the floating point number passed to it, leaving only an integer. If the fraction is exactly 0.5, the integer is rounded to an even number.

Examples

23.45 rounds to 23.00
23.50 rounds to 24.00
23.73 rounds to 24.00
24.50 rounds to 24.00 (rounds to even number)

T$FMul

Single Precision Multiplication

ASM Call

```
TCALL T$Math,T$FMul
```

Input

```
d0.l = Multiplicand
d1.l = Multiplier
```

Output

```
d0.l = Result  ( d0 * d1 )
```

Condition Codes

```
N  Set if result is negative
Z  Set if result is zero
V  Set on underflow or overflow
C  Always cleared
```

Possible Errors

```
TrapV
```

Function

`T$FMul` multiplies two single-precision floating point numbers. Overflow and underflow are indicated by setting the V bit. In either case, a trapv exception is generated. If an underflow caused the exception, zero is returned. If it was an overflow, infinity (with the proper sign) is returned.

T$FNeg

Single Precision Negate

ASM Call

```
TCALL T$Math,T$FNeg
```

Input

```
d0.l = Operand
```

Output

```
d0.l = Result  ( d0 * –1.0 )
```

Condition Codes

```
N  Set if result is negative
Z  Set if result is zero
V  Always cleared
C  Always cleared
```

Possible Errors

None

Function

T$FNeg negates a single-precision floating point operand. To eliminate the overhead of calling this routine, it is simple to change the sign bit of the floating-point number. Be sure to check for a zero number, because this package does not support negative zero.

This example is written as a subroutine and expects the floating-point number to be in d0.

```
Negate  tst.l d0     test for zero
        beq.s Neg10  branch if it is zero
        bchg  #31,d0 change sign bit
Neg10   rts          return
```

T$FSub

Single Precision Subtraction

ASM Call

```
TCALL T$Math,T$FSub
```

Input

```
d0.l = Minuend
d1.l = Subtrahend
```

Output

```
d0.l = Result  ( d0 – d1 )
```

Condition Codes

```
N  Set if result is negative
Z  Set if result is zero
V  Set on underflow or overflow
C  Always cleared
```

Possible Errors

```
TrapV
```

Function

`T$FSub` performs subtraction on two single-precision floating point numbers. Overflow and underflow are indicated by setting the V bit. In either case, a trapv exception is generated. If an underflow caused the exception, zero is returned. If it was an overflow, infinity (with the proper sign) is returned.

T$FtoA

Single-Precision Floating-Point to ASCII

ASM Call

```
TCALL T$Math,T$FtoA
```

Input

```
d0.l = Single-precision floating-point number
d2.l = Low-Word: digits desired in result
       High-Word: digits desired after decimal-point
(a0) = Pointer to conversion buffer
```

Output

```
(a0) = ASCII digit string
d0.l = Two's complement exponent
```

Condition Codes

```
N  Set if the number is negative
Z  Undefined
V  Undefined
C  Undefined
```

Possible Errors

None

Function

The single-precision float passed to T$FtoA is converted to an ASCII string. The conversion terminates as soon as the number of digits requested are converted or when the specified digit after the decimal point is reached; whichever comes first. A null is appended to the end of the string. Therefore, the buffer should be one byte larger than the expected number of digits.

The converted string only contains the mantissa digits. The N bit indicates the sign of the number, and the exponent is returned in register d0.

T$FtoD

Single to Double Floating-Point Conversion

ASM Call

```
TCALL T$Math,T$FtoD
```

Input

```
d0.l = Single-precision floating-point number
```

Output

```
d0:d1 = Double-precision floating-point number
```

Condition Codes

All condition codes are undefined.

Possible Errors

None

Function

`T$FtoD` converts floating-point numbers in single-precision format to double-precision format. No errors are possible and all condition codes are undefined.

T$FtoL

Single-Precision to Signed Long Integer

ASM Call

```
TCALL T$Math,T$FtoL
```

Input

```
d0.l = Single-precision floating-point number
```

Output

```
d0.l = Signed Long Integer
```

Condition Codes

```
N  Undefined
Z  Undefined
V  Set on overflow
C  Undefined
```

Possible Errors

```
TrapV
```

Function

`T$FtoL` converts the integer portion of the floating point number to a signed long integer. The fraction is truncated. If an overflow occurs, the V bit is set and a trapv exception is generated.

T$FtoU

Single Precision to Unsigned Long Integer

ASM Call

```
TCALL T$Math,T$FtoU
```

Input

```
d0.l = Single-precision floating-point number
```

Output

```
d0.l = Unsigned Long Integer
```

Condition Codes

```
N  Undefined
Z  Undefined
V  Set on overflow
C  Undefined
```

Possible Errors

```
TrapV
```

Function

`T$FtoU` converts the integer portion of the floating point number to an unsigned long integer. The fraction is truncated. If an overflow occurs, the V bit is set and a trapv exception is generated.

T$FTrn

Truncate Single-Precision Floating-Point Number

ASM Call

```
TCALL T$Math,T$FTrn
```

Input

```
d0.l = Single-precision floating-point number
```

Output

```
d0.l = Truncated single-precision floating-point number
```

Condition Codes

```
All condition codes are undefined.
```

Possible Errors

None

Function

Floating point numbers consist of two parts: integer and fraction. The purpose of T$FTrn is to truncate the fractional part. For example, if the number passed is 283.75, this function returns 283.00.

T$LDiv

Long (Signed) Divide

ASM Call

```
TCALL T$Math,T$LDiv
```

Input

```
d0.l = Dividend
d1.l = Divisor
```

Output

```
d0.l = Result  ( d0 / d1 )
```

Condition Codes

```
N  Set if result is negative
Z  Set if result is zero
V  Set on divide by zero
C  Always cleared
```

Possible Errors

None

Function

`T$LDiv` performs 32-bit integer division. A division by zero error is indicated by setting the overflow bit. If a division by zero is attempted, infinity (with the proper sign) is returned.

Positive Infinity = $7FFFFFFF
Negative Infinity = $80000000

T$LMod

Long (Signed) Modulus

ASM Call

```
TCALL T$Math,T$LMod
```

Input

```
d0.l = Dividend
d1.l = Divisor
```

Output

```
d0.l = Result  ( Mod(d0/d1) )
```

Condition Codes

```
N  Set if result is negative
Z  Set if result is zero
V  Set on divide by zero
C  Always cleared
```

Possible Errors

None

Function

`T$LMod` returns the remainder (modulo) of the integer division. If an overflow occurs, the V bit is set and zero is returned.

T$LMul

Long (Signed) Multiply

ASM Call

```
TCALL T$Math,T$LMul
```

Input

```
d0.l = Multiplicand
d1.l = Multiplier
```

Output

```
d0.l = Result  ( d0 * d1 )
```

Condition Codes

```
N  Set if result is negative
Z  Set if result is zero
V  Set on overflow
C  Always cleared
```

Possible Errors

None

Function

`T$LMul` performs a 32-bit signed integer multiplication. If an overflow occurs, the V bit is set and the lower 32 bits of the result is returned. If an overflow occurs, the sign of the result is still correct.

T$Log

Natural Logarithm Function

ASM Call

```
TCALL T$Math,T$Log
```

Input

```
d0:d1 = x
d2:d3 = Precision
```

Output

```
d0:d1 = Log(x)
```

Condition Codes

```
C  Set on error
```

Possible Errors

```
E$IllArg
```

Function

`T$Log` returns the natural logarithm of the argument passed. If an illegal argument is passed, an error is returned.

T$Log10

Common Logarithm Function

ASM Call

```
TCALL T$Math,T$Log10
```

Input

```
d0:d1 = x
d2:d3 = Precision
```

Output

```
d0:d1 = Log10(x)
```

Condition Codes

```
C  Set on error
```

Possible Errors

```
E$IllArg
```

Function

`T$Log10` returns the common logarithm of the argument passed. If an illegal argument is passed, an error is returned.

T$LtoA

Signed Integer to ASCII Conversion

ASM Call

```
TCALL T$Math,T$LtoA
```

Input

```
do.1 = Signed long interger
(a0) = Pointer to conversion buffer
```

Output

```
(a0) = ASCII digit string
```

Condition Codes

```
N  Set if the number is negative
Z  Undefined
V  Undefined
C  Undefined
```

Possible Errors

None

Function

The signed long passed to T$LtoA is converted to an ASCII string of ten (10) digits. If the number is smaller than ten digits, it is right justified and padded with leading zeros. A null is appended to the end of the string making the minimum size of the buffer eleven (11) characters.

Important: The N bit indicates the sign and is not included in the ASCII string.

T$LtoD

Signed Long to Double-Precision Floating-Point

ASM Call

```
TCALL T$Math,T$LtoD
```

Input

```
d0.l = Signed long integer
```

Output

```
d0:d1 = Double-precision floating-point number
```

Condition Codes

All condition codes are undefined.

Possible Errors

None

Function

`T$LtoD` converts the signed integer to a double-precision float. No errors are possible and all condition codes are undefined.

T$LtoF

Signed Long to Single-Precision Floating-Point

ASM Call

```
TCALL T$Math,T$LtoF
```

Input

```
d0.l = Signed long integer
```

Output

```
d0.l = Single-precision floating-point number
```

Condition Codes

All condition codes are undefined.

Possible Errors

None

Function

`T$LtoF` converts the signed integer to a single-precision float. No errors are possible and all condition codes are undefined.

T$Power

Power Function

ASM Call

```
TCALL T$Math,T$Power
```

Input

```
d0:d1 = x
d2:d3 = y
d4:d5 = Precision
```

Output

```
d0:d1 = x^y
```

Condition Codes

```
C  Set on error
```

Possible Errors

```
E$IllArg
```

Function

`T$Power` performs the power function on the arguments passed. That is, it raises x to the y power. If an illegal argument is passed, an error is returned.

T$Sin

Tangent Function

ASM Call

```
TCALL T$Math,T$Sin
```

Input

```
d0:d1 = x (in radians)
d2:d3 = Precision
```

Output

```
d0:d1 = Sin(x)
```

Condition Codes

```
C  Always clear
```

Possible Errors

None

Function

`T$Sin` returns the sine() of an angle. The angle must be specified in radians. No errors are possible, and all condition codes are undefined.

T$Sqrt

Square Root Function

ASM Call

```
TCALL T$Math,T$Sqrt
```

Input

```
d0:d1 = x
d2:d3 = Precision
```

Output

```
d0:d1 = Sqrt(x)
```

Condition Codes

```
C  Set on error
```

Possible Errors

```
E$IllArg
```

Function

`T$Sqrt` returns the square root of the argument passed. If an illegal argument is passed an error is returned.

T$Tan

Tangent Function

ASM Call

```
TCALL T$Math,T$Tan
```

Input

```
d0:d1 = x (in radians)
d2:d3 = Precision
```

Output

```
d0:d1 = Tan(x)
```

Condition Codes

```
C  Always clear
```

Possible Errors

None

Function

`T$Tan` returns the tangent() of an angle. The angle must be specified in radians. No errors are possible, and all condition codes are undefined.

T$UDiv

Unsigned Divide

ASM Call

```
TCALL T$Math,T$UDiv
```

Input

```
d0.l = Dividend
d1.l = Divisor
```

Output

```
d0.l = Result  ( d0 / d1 )
```

Condition Codes

```
N  Undefined
Z  Set if result is zero
V  Set on divide by zero
C  Always cleared
```

Possible Errors

None

Function

`T$UDiv` performs 32-bit unsigned integer division. The overflow bit is set when a division by zero error occurs. If a division by zero is attempted, infinity ($FFFFFFFF) is returned.

T$UMod

Unsigned Modulus

ASM Call

```
TCALL T$Math,T$UMod
```

Input

```
d0.l = Dividend
d1.l = Divisor
```

Output

```
d0.l = Result  ( Mod(d0/d1) )
```

Condition Codes

```
N  Undefined
Z  Set if result is zero
V  Set on divide by zero
C  Always cleared
```

Possible Errors

None

Function

`T$UMod` returns the remainder (modulo) of the integer division. If an overflow occurs, the V bit is set and zero is returned.

T$UMul

Unsigned Multiply

ASM Call

```
TCALL T$Math,T$UMul
```

Input

```
d0.l = Multiplicand
d1.l = Multiplier
```

Output

```
d0.l = Result  ( d0 * d1 )
```

Condition Codes

```
N  Undefined
Z  Set if result is zero
V  Set on overflow
C  Always cleared
```

Possible Errors

None

Function

`T$UMul` performs a 32-bit unsigned integer multiplication. If an overflow occurs, the V bit is set and the lower 32 bits of the result is returned.

T$UtoA

Unsigned Integer to ASCII Conversion

ASM Call

```
TCALL T$Math,T$UtoA
```

Input

```
d0.l = Unsigned long integer
(a0) = Pointer to conversion buffer
```

Output

```
(a0) = ASCII digit string
```

Condition Codes

```
All condition codes are undefined.
```

Possible Errors

None

Function

The unsigned long passed to T$UtoA is converted to an ASCII string of ten digits. If the number is smaller than ten digits, it is right justified and padded with leading zeros. A null is appended to the end of the string, making the minimum size of the buffer eleven characters.

T$UtoD

Unsigned Long to Double-Precision Floating-Point

ASM Call

```
TCALL T$Math,T$UtoD
```

Input

```
d0.l = Unsigned long integer
```

Output

```
d0:d1 = Double-precision floating-point number
```

Condition Codes

All condition codes are undefined.

Possible Errors

None

Function

`T$UtoD` converts the unsigned integer to a double-precision float. No errors are possible and all condition codes are undefined.

T$UtoF

Unsigned Long to Single-Precision Floating-Point

ASM Call

```
TCALL T$Math,T$UtoF
```

Input

```
d0.l = Unsigned long integer
```

Output

```
d0.l = Single-precision floating-point number
```

Condition Codes

All condition codes are undefined.

Possible Errors

None

Function

`T$UtoF` converts the unsigned integer to a single-precision float. No errors are possible and all condition codes are undefined.

Chapter 7

OS-9 File System

Disk File Organization

RBF supports a tree-structured file system. The physical disk organization is designed for efficient use of disk space, resistance to accidental damage, and fast file access. The system also has the advantage of relative simplicity.

Basic Disk Organization

RBF supports logical sector sizes in integral binary multiples from 256 to 32768 bytes. If you use a disk system that cannot directly support the logical sector size (for example, 256 byte logical sectors on a 512-byte physical sector disk), the driver module must divide or combine sectors as required to simulate the required logical size.

Many disks are physically addressed by track number, surface number, and sector number. To eliminate hardware dependencies, OS-9 uses a **logical sector number** (LSN) to identify each sector without regard to track and surface numbering.

It is the responsibility of the disk driver module or the disk controller to map logical sector numbers to track/surface/sector addresses. OS-9's file system uses LSNs from 0 to (n–1), where "n" is the total number of sectors on the drive.

Important: All sector addresses discussed in this section refer to LSNs.

The format utility initializes the file system on blank or recycled media by creating the track/surface/sector structure. `format` also tests the media for bad sectors and automatically excludes them from the file system.

Every OS-9 disk has the same basic structure. An **identification sector** is located in logical sector zero (LSN 0). It contains a description of the physical and logical format of the storage volume (disk media). A **disk allocation map** usually begins in logical sector one (LSN 1). This indicates which disk sectors are free for use in new or expanded files. A **root directory** of the volume begins immediately after the disk allocation map.

Identification Sector

LSN zero always contains the identification sector (see Figure 7.1). It describes the physical format of the disk, the size of the allocation map, and the location of the root directory. It also contains the volume name, date and time of creation, etc. If the disk is a bootable system disk it also has the starting LSN and size of the OS9Boot file.

Figure 7.1
Identification Sector Description

Addr	Size	Name	Description
$00	3	DD_TOT	Total number of sectors on media
$03	1	DD_TKS	Track size in sectors
$04	2	DD_MAP	Number of bytes in allocation map
$06	2	DD_BIT	Number of sectors/bit (cluster size)
$08	3	DD_DIR	LSN of root directory file descriptor
$0B	2	DD_OWN	Owner ID
$0D	1	DD_ATT	Attributes
$0E	2	DD_DSK	Disk ID
$10	1	DD_FMT	Disk Format; density/sides
			Bit 0:0 = single side
			1 = double side
			Bit 1:0 = single density (FM)
			1 = double density (MFM)
			Bit 2:1 = double track (96 TPI/135 TPI)
			Bit 3:1 = quad track density (192 TPI)
			Bit 4:1 = octal track density (384 TPI)
$11	2	DD_SPT	Sectors/track (two byte value DD_TKS)
$13	2	DD_RES	Reserved for future use
$15	3	DD_BT	System bootstrap LSN
$18	2	DD_BSZ	Size of system bootstrap
$1A	5	DD_DAT	Creation date
$1F	32	DD_NAM	Volume name
$3F	32	DD_OPT	Path descriptor options
$5F	1		Reserved
$60	4	DD_SYNC	Media integrity code
$64	4	DD_MapLSN	Bitmap starting sector number (0=LSN 1)
$68	2	DD_LSNSize	Media logical sector size (0=256)
$6A	2	DD_VersID	Sector 0 Version ID

Allocation Map

The allocation map shows which sectors are allocated to files and which are free for future use. `DD_MapLSN` specifies the allocation map start address, which is usually 1. If this field is 0, assume an address of 1. The size of the map varies according to how many bits are needed. Each bit in the allocation map represents a cluster on the disk. If a bit is set, the cluster is considered to be in use, defective, or non-existent. `DD_MAP` (see Figure 7.1) specifies the actual number of bytes used in the map.

Important: The DD_Bit variable specifies the number of sectors per cluster. The number of sectors per cluster is always an integral power of two.

The format utility sets the size of the allocation map depending on the size and number of sectors per cluster. You can select the number of sectors per cluster on the command line when invoking the format utility.

Root Directory

The root directory file is the parent directory of all other files and directories on the disk. It is the directory accessed using the physical device name (such as /d1). Usually, it immediately follows the allocation map. The location of the root directory file descriptor is specified in DD_DIR (see Figure 7.1).

Basic File Structure

OS-9 uses a multiple-contiguous-segment type of file structure. Segments are physically contiguous sectors that store the file's data. If all the data cannot be stored in a single segment, additional segments are allocated to the file. This may occur if a file is expanded after creation, or if a sufficient number of contiguous free sectors is not available.

The OS-9 segmentation method was designed to keep a file's data sectors in as close physical proximity as possible to minimize disk head movement. Frequently, files (especially small files) have only one segment. This results in the fastest possible access time. Therefore, it is good practice to initialize the size of a file to the maximum expected size during or immediately after its creation. This allows OS-9 to optimize its storage allocation.

All files have a sector called a file descriptor sector, or FD. FD contains a list of the data segments with their starting LSNs and sizes. This is also where information such as file attributes, owner, and time of last modification is stored. Only the system uses this sector; it is not directly accessible by the user. The table in Figure 7.2 describes the contents of a file descriptor.

Important: *Offset* refers to the location of a field, relative to the starting address of the file descriptor. Offsets are resolved in assembly code by using the names shown here and linking the module with the relocatable library: sys.l or usr.l.

Figure 7.2
File Descriptor Content Description

Offset	Size	Name	Description
$00	1	FD_ATT	File Attributes: D S PE PW PR E W R
$01	2	FD_OWN	Owner's User ID
$03	5	FD_DAT	Date Last Modified: Y M D H M
$08	1	FD_LNK	Link Count
$09	4	FD_SIZ	File Size (number of bytes)
$0D	3	FD_CREAT	Date Created: Y M D
$10	240	FD_SEG	Segment List: see below

The attribute byte (FD_ATT) contains the file permission bits. Bit 7 is set to indicate a directory file, bit 6 indicates a non-sharable file, bit 5 indicates public execute, bit 4 indicates public write, etc.

The date last modified (FD_DAT) changes when a file is opened in write or update mode. This is useful for making date-dependant backups.

The segment list (FD_SEG) consists of a series of five-byte entries, continuing until the end of the logical sector. For 256-byte sectors, this results in 48 entries. These entries have the size and address of each block of storage used by the file in logical order. Each entry has a three-byte logical sector number that specifies the beginning of the block and a two-byte block size (in sectors). Unused segments must be zero.

The RBF file manager maintains the file pointer, logical end-of-file, etc., used by application software and converts them to the logical disk sector number using the data in the segment list.

You do not have to be concerned with physical sectors. OS-9 provides fast random access to data stored anywhere in the file. All the information required to map the logical file pointer to a physical sector number is packaged in the file descriptor sector. This makes OS-9's record-locking functions very efficient.

Segment Allocation

Each device descriptor module has a value called a **segment allocation *size***. It specifies the minimum number of sectors to allocate to a new segment. The goal is to avoid a large number of tiny segments when a file is expanded. If your system uses a small number of large files, this field should be set to a relatively high value, and vice versa.

When a file is created, it has no data segments allocated to it. Write operations past the current end-of-file (the first write is always past the end-of-file) cause allocation of additional sectors to the file. Subsequent expansions of the file are also generally made in minimum allocation increments.

Important: An attempt is made to expand the last segment before attempting to add a new segment.

If not all of the allocated sectors are used when the file is closed, the segment is truncated and any unused sectors are de-allocated in the bitmap. This strategy does not work very well for random-access data bases that expand frequently by only a few records. The segment list is rapidly filled with small segments. A provision has been added to prevent this from being a problem.

If a file (opened in write or update mode) is closed when it is not at end-of-file, the last segment of the file is not truncated. To be effective, all programs that deal with the file in write or update mode must ensure that they do not close the file while at end-of-file, or the file will lose any excess space it may have. The easiest way to ensure this is to do a seek(0) before closing the file. This method was chosen because random access files are frequently somewhere other than end-of-file, and sequential files are almost always at end-of-file when closed.

Directory File Format

Directory files have the same physical structure as other files with one exception: RBF must impose a convention for the logical contents of a directory file.

A directory file consists of an integral number of 32-byte entries. The end of the directory is indicated by the normal end-of-file. Each entry consists of a field for the file name and a field for the file's file descriptor address.

The file name field (DIR_NM) is 28 bytes long (bytes 0-27) and has the sign bit of the last character of the file name set. The first byte is set to zero, indicating a deleted or unused entry. The file descriptor address field (DIR_FD) is three bytes long (bytes 29-31) and is the LSN of the file's FD sector. Byte 28 is not used and must be zero.

When a directory file is created, two entries are automatically created: the dot (.) and double dot (..) directory entries. These specify the directory and its parent directory, respectively.

Raw Physical I/O on RBF Devices

You can open an entire disk as one logical file. This allows access of any byte(s) or sector(s) by physical address without regard to the normal file system. This feature is provided for diagnostic and utility programs that must be able to read and write to ordinarily non-accessible disk sectors.

A device is opened for physical I/O by appending the at (@) character to the device name. For example, you can open the device /d2 for raw physical I/O under the pathlist /d2@.

Standard open, close, read, write, and seek system calls are used for physical I/O. A seek system call positions the file pointer to the actual disk physical address of any byte. To read a specific sector, perform a seek to the address computed by multiplying the LSN by the logical sector size of the media. You can find the logical sector size in the PD_SctSiz field of the path descriptor (if 0, assume a value of 256 bytes). For example, on 1024-byte logical media, to read sector 3, perform a seek to address 3072 (1024 * 3), followed by a read system call requesting 1024 bytes.

If the number of sectors per track of the disk is known or read from the identification sector, any track/sector address can be readily converted to a byte address for physical I/O.

ATTENTION: Use extreme care with the special “@” file in update mode. To keep system overhead low, record locking routines only check for conflicts on paths opened for the same file. The “@” file is considered different from any other file, and therefore only conforms to record lockouts with other users of the “@” file.

ATTENTION: Improper physical I/O operations can corrupt the file system. Take great care when writing to a raw device. Physical I/O calls also bypass the file security system. For this reason, only super-users are allowed to open the raw device for write permit. Non-super-users are only permitted to read the identification sector (LSN 0) and the allocation bitmap. Attempts to read past this return an end-of-file error.

Record Locking

Record locking is a general term that refers to preserving the integrity of files that more than one user or process can access. OS-9 record locking is designed to be as invisible as possible to application programs.

Most programs may be written without special concern for multi-user activity.

Simply stated, record locking involves:

- recognizing when a process is trying to read a record that another process may be modifying
- deferring the read request until the record is safe

This is referred to as conflict detection and prevention. RBF record locking also handles non-sharable files and deadlock detection.

Record Locking and Unlocking

Conflict detection must determine when a record is in the process of being updated. RBF provides true record locking on a byte basis. A typical record update sequence is:

`OS9 I$Read`	program reads record	RECORD IS LOCKED
.		
.	program updates record	
.		
`OS9 I$Seek`	reposition to record	
`OS9 I$Write`	record is rewritten	RECORD IS RELEASED

When a file is opened in update mode, *ANY* read causes the record to be locked out because RBF does not know in advance if the record will be updated. The record remains locked until the next read, write, or close occurs. Reading files that are opened in read or execute modes does not cause record locking to occur because records cannot be updated in these two modes.

A subtle but nasty problem exists for programs that interrogate a data base and occasionally update its data. When a user looks up a particular record, the record could be locked out indefinitely if the program neglects to release it. The problem is characteristic of record locking systems; you can avoid it by careful programming.

Important: Only one portion of a file may be locked out at one time. If an application requires more than one record to be locked out, multiple paths to the same file may be opened with each path having its own record locked out. RBF notices that the same process owns both paths and keeps them from locking each other out. Alternatively, the entire file may be locked out, the records updated, and the file released.

Non-sharable Files

You may use file locking when an entire file is considered unsafe for use by more than one user. On rare occasions, you need to create a **non-sharable file**. A non-sharable file can never be accessed by more than one process at a time. Make a file non-sharable by setting the single user (S) bit in the file's attribute byte. You can set the bit when you create the file, or later using the attr utility.

If the single-user bit is set, only one process may open the file at a time. If another process attempts to open the file, error (#253) is returned.

More commonly, a file needs to be non-sharable only during the execution of a specific program. Accomplish this by opening the file with the single-user bit set in the access mode parameter.

For example, if a file is opened as a non-sharable file, when it is being sorted it is treated as though it had a single-user attribute. If the file was already opened by another process, an error (#253) is returned.

A necessary quirk of non-sharable files is that they may be duplicated using the I$Dup system call, or inherited. A non-sharable file could therefore actually become accessible to more than one process at a time. Non-sharable only means that the file may be opened once. It is usually a very bad idea to have two processes actively using any disk file through the same (inherited) path.

End of File Lock

An EOF lock occurs when the user reads or writes data at the end of file. The user keeps the end of file locked until a read or write is performed that is not at the end of the file. EOF lock is the only time that a write call automatically causes lock out of any part of the file. This avoids problems that could occur when two users try to simultaneously extend a file.

An extremely useful side effect occurs when a program creates a file for sequential output. As soon as the file is created, EOF lock is gained, and no other process is able to pass the writer in processing the file.

For example, if you redirect an assembly listing to a disk file, a spooler utility can open and begin listing the file before the assembler has written even the first line of output. Record locking always keeps the spooler one step behind the assembler, making the listing come out as desired.

Deadlock Detection

A deadlock can occur when two processes attempt to gain control of the same two disk areas simultaneously. If each process gets one area (locking out the other process), both processes are stuck permanently, waiting for a segment that can never become free. This situation is a general problem that is not restricted to any particular record locking method or operating system.

If this occurs, a deadlock error (#254) is returned to the process that caused it to be detected. It is easy to create programs that, when executed concurrently, generate lots of deadlock errors. The easiest way to avoid them is to access records of shared files in the same sequences in all processes that may be run simultaneously. For example, always read the index file before the data file, never the other way around.

When a deadlock error does occur, it is not sufficient for a program to simply re-try the operation in error. If all processes used this strategy, none would ever succeed. At least one process must release its control over a requested segment for any to proceed.

Record Locking Details for I/O Functions

Operation:	Description:
Open/Create	The most important guideline to follow when opening files is: Do not open a file for update if you only intend to read. Files open for read only do not cause records to be locked out, and they generally help the system to run faster. If shared files are routinely opened for update on a multi-user system, users can become hopelessly record-locked for extended periods of time. Use the special "@" file in update mode with extreme care. To keep system overhead low, record locking routines only check for conflicts on paths opened for the same file. The "@" file is considered different from any other file, and therefore only conforms to record lockouts with other users of the "@" file.
Read/ReadLine	Read and ReadLine cause lock out of records only if the file is open in update mode. The locked out area includes all bytes starting with the current file pointer and extending for the number of bytes requested. For example, if you make a ReadLine call for 256 bytes, exactly 256 bytes are locked out, regardless of how many bytes are actually read before a carriage return is encountered. EOF lock occurs if the bytes requested include the current end-of-file. A record remains locked until any of the following occur: • Another read is performed • A write is performed • The file is closed • A record lock SetStat is issued Releasing a record does not normally release EOF lock. Any read or write of zero bytes releases any record lock, EOF lock, or File lock.
Write/WriteLine	Write calls always release any record that is locked out. In addition, a write of zero bytes releases EOF lock and File lock. Writing usually does not lock out any portion of the file unless it occurs at end of file when it will gain EOF lock.
Seek	Seek does not effect record locking.
SetStatus	There are two SetStat codes to deal with record locking: SS_Lock locks or releases part of a file. SS_Ticks sets the length of time a program will wait for a locked record. See the I$SetStat entry in OS-9 System Calls (chapter 2) for a description of the codes.

File Security

Each file has a group/user ID that identifies the file's owner. These are copied from the current process descriptor when the file is created. Usually, a file's owner ID is not changed.

An attribute byte is also specified when a file is created. The file's attribute byte tells RBF in which modes the file may be accessed. Together with the file's owner ID, the attribute byte provides (some) file security.

The attribute byte has two sets of bits to indicate whether a file may be opened for read, write, or execute by the **owner** or the **public**. In this context, the file's owner is any user with the same group ID as the file's creator. Public means any user with a different group ID.

Whenever a file is opened, access permissions are checked on all directories specified in the pathlist, as well as the file itself. If you do not have permission to read a directory, you may not read any files in that directory.

Any **super-user** (a user with group ID of zero) may access any file in the system. Files owned by the super-user cannot be accessed by users of any other group unless specific access permissions are set. Files containing modules owned by the super-user must also be owned by the super-user. If not, the modules contained within the file are not loaded.

ATTENTION: The system manager should exercise caution when assigning group/user IDs. The RBF File Descriptor stores the group/user ID in a two byte field (FD_OWN). The group/user ID that resides in the password file is permitted two bytes for the group ID and two bytes for the user ID. RBF only reads the low order byte of both the group and user ID. Consequently, a user with the ID of 256.512 is mistaken for the super user by RBF.

Appendix A

Example Code

Introduction

Use the examples in this section as guides in creating your own modules; they should not be considered the most current software. Software for your individual system may be different.

Init Module

```
Microware OS-9/68020 Resident Macro Assembler V2.9  90/09/10  19:55  Page     1
Init: OS-9 Configuration Module -
00001                       nam      Init: OS-9 Configuration Module
00048 *
00049  00000016 Edition     equ      22             current edition number
00050
00051  00000c00 Typ_Lang    set      (Systm<<8)+0
00052  00008000 Attr_Rev    set      (ReEnt<<8)+0
00053                       psect    init,Typ_Lang,Attr_Rev,Edition,0,0
00054
00055 * Configuration constants (default; changable in "systype.d" file)
00056 *
00057 * Constants that use VALUES (e.g. CPUTyp set 68020) may appear anywhere
00058 * in the "systype.d" file.
00059 * Constants that use LABELS (e.g. Compat set ZapMem) MUST appear OUTSIDE
00060 * the CONFIG macro and must be conditionalized such that they are
00061 * only invoked when this file (init.a) is being assembled.
00062 * If they are placed inside the CONFIG macro, then the over-ride will not
00063 * take effect.
00064 * If they are placed outside the macro and not conditionalized then
00065 * "illegal external reference" errors will result when making other files.
00066 * The label _INITMOD provides the mechanism to ensure that the desired
00067 * operations will result.
00068 *
00069 * example systype.d setup:
00070 *
00071 * CONFIG macro
00072 *   <body of macro>
00073 *  endm
00074 *  Slice set 10
00075 *  ifdef _INITMOD
00076 * Compat set ZapMem patternize memory
00077 *  endc
00078 *
00079
00080 * flag reading init module (so that local labels can be over-ridden)
00081  00000001 _INITMOD   equ    1              flag reading init module
00082
00083 000109a0 CPUTyp     set    68000        cpu type (68008/68000/68010/etc.)
00084 00000001 Level      set    1            OS-9 Level One
```

```
00085 00000002 Vers       set    2            Version 2.4
00086 00000004 Revis      set    4
00087 00000001 Edit       set    1            Edition
00088 00000000 IP_ID      set    0            interprocessor identification code
00089 00000000 Site       set    0            installation site code
00090 00000080 MDirSz     set    128          initial mod directory size (unused)
00091 00000020 PollSz     set    32           IRQ polling table size (fixed)
00092 00000020 DevCnt     set    32           device table size (fixed)
00093 00000040 Procs      set    64           initial process table size
00094 00000040 Paths      set    64           initial path table size
00095 00000002 Slice      set    2            ticks per time slice
00096 00000080 SysPri     set    128          initial system priority
00097 00000000 MinPty     set    0            initial sys min executable priority
00098 00000000 MaxAge     set    0            initial sys max natural age limit
00099 00000000 MaxMem     set    0            top of RAM (unused)
00100 00000000 Events     set    0            initial event table size (div by 8)
00101 00000000 Compat     set    0            version smoothing byte
00102 00000400 StackSz    set    1024         IRQ Stack Size in bytes (must be 1k
                                               <= StackSz < 256k)
00103 00000000 ColdRetrys set    0            number of retries for coldstart's
                                               "chd" before failing
00104
00105 * Compat flag bit definitions
00106 00000001 SlowIRQ    equ    1            save all regs during IRQ processing
00107 00000002 NoStop     equ    1<<1         don't use 'stop' instruction
00108 00000004 NoGhost    equ    1<<2         don't retain Sticky memory modules
00109 00000008 NoBurst    equ    1<<3         don't enable 68030 cache burst mode
00110 00000010 ZapMem     equ    1<<4         wipe out mem that is allocated/freed
00111 00000020 NoClock    equ    1<<5         don't start sys clock during coldstart
00112
00113 * Compat2 flag bit definitions
00114 00000001 ExtC_I     equ    1<<0         ext instruction cache is coherent
00115 00000002 ExtC_D     equ    1<<1         external data cache is coherent
00116 00000004 OnC_I      equ    1<<2         on-chip inst cache is coherent
00117 00000008 OnC_D      equ    1<<3         on-chip data cache is coherent
00118 00000080 DDIO       equ    1<<7         don't disable data caching when in I/O
00119
00120                     use     defsfile (any above defs may be overridden in
                                            defsfile)
00001
00002                     use      ../DEFS/oskdefs.d
00001                     opt      -l
00003                     use      ./systype.d
00001 *
00002 * System Definitions for MVME147 System
00003 *
00004 * VERSION FOR DELTA
00005                      opt      -l
00004
00005
00121
00132
00133 * Configuration module body
00134 0000 0000          dc.l   MaxMem         (unused)
00135 0004 0020          dc.w   PollSz         IRQ polling table
00136 0006 0020          dc.w   DevCnt         device table size
```

```
00137 0008 0040          dc.w   Procs          initial process table size
00138 000a 0040          dc.w   Paths          initial path table size
00139 000c 0076          dc.w   SysParam       param string for first executable mod
00140 000e 0070          dc.w   SysStart       first executable module name offset
00141 0010 008b          dc.w   SysDev         system default device name offset
00142 0012 008f          dc.w   ConsolNm       standard I/O pathlist name offset
00143 0014 009b          dc.w   Extens         Customization module name offset
00144 0016 0095          dc.w   ClockNm        clock module name offset
00145 0018 0014          dc.w   Slice          number of ticks per time slice
00146 001a 0000          dc.w   IP_ID          interprocessor identification
00147 001c 0000          dc.l   Site           installation site code
00148 0020 0062          dc.w   MainFram       installation name offset
00149 0022 0001          dc.l   CPUTyp         specific 68000 family proc in use
00150 0026 0102          dc.b   Level,Vers,Revis,Edit OS-9 Level
00151 002a 0054          dc.w   OS9Rev         OS-9 revision string offset
00152 002c 0080          dc.w   SysPri         initial system priority
00153 002e 0000          dc.w   MinPty         initial sys min executable priority
00154 0030 0000          dc.w   MaxAge         maximum system natural age limit
00155 0032 0000          dc.l   MDirSz         module directory size (unused)
00156 0036 0000          dc.w   Events         initial event table size (no.r of
                                                entries)
00157 0038   10          dc.b   Compat         version change smooth byte
00158 0039   83          dc.b   Compat2        version change smooth byte #2
00159 003a 00b6          dc.w   MemList        memory definitions
00160 003c 0400          dc.w   StackSz/4      IRQ stack size (in longwords)
00161 003e 0000          dc.w   ColdRetrys     coldstart's "chd" retry count
00162 0040 0000          dc.w   0,0,0,0,0      reserved
00163 004a 0000          dc.w   0,0,0,0,0      reserved
00164
00165 * Configuration name strings
00166 0054 4f53 OS9Rev     dc.b     "OS-9/68K V",Vers+'0',".",Revis+'0',0
00167
00168 * The remaining names are defined in the "systype.d" macro
00169                       CONFIG
00170 0062 4465+MainFram   dc.b     "Delta MVME147",0
00172 0070 7368+SysStart   dc.b     "shell",0      name of initial module to execute
00173 0076=7461+SysParam   dc.b     "tapestart; ex sysgo",C$CR,0
Init: OS-9 Configuration Module -
00174 008b 2f64+SysDev     dc.b     "/dd",0        initial system disk pathlist
00184 008f 2f74+ConsolNm   dc.b     "/term",0      console terminal pathlist
00185 0095 746b+ClockNm    dc.b     "tk147",0      clock module name
00186 009b 4f53+Extens     dc.b     "OS9P2 ssm syscache" include mmu, caching.
00188 00b5   00+           dc.b     0
00189  000000b6+           align
00190          +MemList
00191                       MemType
SYSRAM,250,B_USER,ProbeSize,CPUBeg,BootMemEnd,OnBoard,CPUBeg+TRANS
00192 00b6=0000+           dc.w     SYSRAM,250,B_USER,ProbeSize>>4 type, priority,
                                    access, search block size
00193 00be 0000+           dc.l     CPUBeg,BootMemEnd low, high limits (where it
                                    appears on local address bus)
00194 00c6 00fa+           dc.w     OnBoard,0      offset to description string
                                                  (zero if none), reserved
00195 00ca 0000+           dc.l     CPUBeg+TRANS,0,0 address translation adjustment
                                                    (for DMA, etc.), reserved
00199  MemType  SYSRAM,240,B_USER+B_PARITY,ProbeSize,BootMemEnd,UserMemEnd,OffBoard,0
```

```
00200 00d6=0000+          dc.w     SYSRAM,240,B_USER+B_PARITY,ProbeSize>>4 type,
                                   priority, access, search block size
00201 00de 0040+          dc.l     BootMemEnd,UserMemEnd low, high limits (where it
                                   appears on local address bus)
00202 00e6 0107+          dc.w     OffBoard,0     offset to description string
                                                  (zero if none), reserved
00203 00ea 0000+          dc.l     0,0,0          address translation adjustment
                                                  (for DMA, etc.), reserved
00207 00f6 0000+          dc.l     0              terminate list
00208 00fa 6f6e+OnBoard   dc.b     “on–board ram”,0
00209 0107 766d+OffBoard  dc.b     “vme bus ram”,0
00210
00214
00218
00219 * define default caching modes (CPUTyp and system specific)
00220 * NOTE:  the following rules should be applied in determining
00221 *        the “coherency” of a cache and setting up the Compat2
00222 *        cache function flags:
00223 *
00224 *         – if the cache does not exits, then it is always coherent.
00225 *         – the on–chip cache coherency is not changable, except
00226 *           for the 68040.  If a 68040 system is used with
00227 *           bus–snooping disabled, then that fact should be registered
00228 *           by the user defining the label NoSnoop040 in their local
00229 *           “systype.d” file.
00230 *         – the coherency of external caches is indicated by the
00231 *           SnoopExt definition.  If the external caches are
00232 *           coherent or non–existant, then the label SnoopExt
00233 *           should be defined in “systype.d”.
00234 *         – the kernel will disable data caching when calling a file
00235 *           manager, unless the “NoDataDis” label is defined.
00236 *           Disabling data caching is required for systems that have
00237 *           drivers that use dma and don’t perform any explicit data
00238 *           cache flushing.  If your system does NOT use dma drivers,
00239 *           or the drivers care for the cache, then the NoDataDis
00240 *           label should be defined in “systype.d”.
00241 *
00243
00246 * external caches are coherent or absent
00247  00000003 ExtCache   equ      ExtC_I!ExtC_D
00252
00261  00000003 Compat2    set      ExtCache       68030 on–chip caches are NOT snoopy
00270
00271 * add “don’t disable data cache when in I/O” to Compat2
00273  00000083 Compat2    set      Compat2!DDIO
00275
00277
00278  00000114            ends
Errors: 00000
Memory used: 45k
Elapsed time: 6 second(s)
```

Sysgo Module

```
Microware OS-9/68000 Resident Macro Assembler V1.6  86/11/04   Page 1  sysgo.a
Sysgo – OS-9/68000 Initial (startup) module
00001                       nam     Sysgo
00002                       ttl     OS-9/68000     Initial (startup) module
00003
00015  00000004 Edition     equ     4              current edition number
00016
00017  00000101 Typ_Lang    set     (Prgrm<<8)+Objct
00018  00000000 Attr_Rev    set     0              (non-re- entrant)
00019                       psect   sysgo,Typ_Lang,Attr_Rev,Edition,128,Entry
00020
00021                       use     defsfile
00022
00023                       vsect
00024  00000000             ds.b    255            stack space
00025  00000000             ends
00026
00027 0000=4e40 Intercpt    os9     F$RTE          return from intercept00028
00029 0004 41fa Entry       lea     Intercpt(pc),a0
00030 0008=4e40             os9     F$Icpt
00031 000c 41fa             lea     CmdStr(pc),a0  default execution dir ptr
00032 0010 7004             moveq   #Exec_,d0      execution mode
00033 0012=4e40             os9     I$ChgDir       chg exec dir (ignore errs)
00034 0016 640c             bcc.s   Entry10        continue if no error
00035 0018 7001             moveq   #1,d0          std output path
00036 001a 721a             moveq   #ChdErrSz,d1   size
00037 001c 41fa             lea     ChdErrMs(pc),a0 “Help, I can’t find CMDS”
00038 0020=4e40             os9     I$WritLn       output error message
00039
00040 * Process startup file
00041 0024 7000 Entry10     moveq   #0,d0          std input path
00042 0026=4e40             os9     I$Dup          clone it
00043 002a 3e00             move.w  d0,d7          save cloned path number
00044 002c 7000             moveq   #0,d0          std input path
00045 002e=4e40             os9     I$Close
00046 0032 303c             move.w  #Read_,d0
00047 0036 41fa             lea     Startup(pcr),a0 “startup” pathlist
00048 003a=4e40             os9     I$Open         open startup file
00049 003e 640e             bcc.s   Entry15        continue if no error
00050 0040 7001             moveq   #1,d0          std output path
00051 0042 7220             moveq   #StarErSz,d1   size of startup error msg
00052 0044 41fa             lea     StarErMs(pc),a0 “Can’t find ’startup’”
00053 0048=4e40             os9     I$WritLn       output error message
00054 004c 6032             bra.s   Entry25
00055
00056 004e 7000 Entry15     moveq   #0,d0          any type module
00057 0050 7200             moveq   #0,d1          no add’l default mem size
00058 0052 7406             moveq   #StartPSz,d2   sz of startup shell params
00059 0054 7603             moveq   #3,d3          copy three std I/O paths
00060 0056 7800             moveq   #0,d4          same priority
00061 0058 41fa             lea     ShellStr(pcr),a0 shell name
00062 005c 43fa             lea     StartPrm(pcr),a1 initial parameters
00063 0060=4e40             os9     F$Fork         fork shell
00064 0064 6410             bcc.s   Entry20        continue if no error
```

```
00065 0066 7001            moveq    #1,d0          std output path
00066 0068 7219            moveq    #FrkErrSz,d1   size
00067 006a 41fa            lea      FrkErrMs(pc),a0 “oh no, can’t fork Shell”
00068 006e=4e40            os9      I$WritLn       output error message
00069 0072=4e40            os9      F$SysDbg       crash system
00070
00071 0076=4e40 Entry20    os9      F$Wait         wait for death,ignore error
00072 007a 7000            moveq    #0,d0          std input path
00073 007c=4e40            os9      I$Close        close redirected “startup”
00074 0080 3007 Entry25    move.w   d7,d0
00075 0082=4e40            os9      I$Dup          restore original std input
00076 0086 3007            move.w   d7,d0
00077 0088=4e40            os9      I$Close        remove cloned path
00078
00079 008c 7000 Loop       moveq    #0,d0          any type module
00080 008e 7200            moveq    #0,d1          default memory size
00081 0090 7401            moveq    #1,d2          one parameter byte (CR)
00082 0092 7603            moveq    #3,d3          copy std I/O paths
00083 0094 7800            moveq    #0,d4          same priority
00084 0096 41fa            lea      ShellStr(pcr),a0 shell name
00085 009a 43fa            lea      CRChar(pcr),a1 null paramter string
00086 009e=4e40            os9      F$Fork         fork shell
00087 00a2 650a            bcs.s    ForkErr        abort if error
00088 00a4=4e40            os9      F$Wait         wait for it to die
00089 00a8 6504            bcs.s    ForkErr
00090 00aa 4a41            tst.w    d1             zero status?
00091 00ac 67de            beq.s    Loop           loop if so
00092 00ae=4e40 ForkErr    os9      F$PErr         print error message
00093 00b2 60d8            bra.s    Loop
00094
00095 00b4 7368 ShellStr   dc.b     “shell”,0
00096 00ba=5379 FrkErrMs   dc.b     “Sysgo can’t fork ’shell’”,C$CR
00097  00000019 FrkErrSz   equ      *-FrkErrMs
00098
00099 00d3 434d CmdStr     dc.b     “CMDS”,0
00100 00d8=5379 ChdErrMs   dc.b     “Sysgo can’t chx to ’CMDS’”,C$CR
00101  0000001a ChdErrSz   equ      *-ChdErrMs
00102
00103 00f2 7374 Startup    dc.b     “startup”,0
00104 00fa=5379 StarErMs   dc.b     “Sysgo can’t open ’startup’ file”,C$CR
00105  00000020 StarErSz   equ      *-StarErMs
00106
00107 011a 2d6e StartPrm   dc.b     “-npxt”
00108 011f=  00 CRChar     dc.b     C$CR
00109  00000006 StartPSz   equ      *-StartPrm
00110  00000120            ends
00111
Errors: 00000
Memory used: 31k
Elapsed time: 21 second(s)
```

Signals: Example Program

The following program demonstrates a subroutine that reads a /n terminated string from a terminal with a ten second timeout between the characters. This program is designed to illustrate signal usage; it does not contain any error checking.

The _ss_ssig(path, value) library call notifies that operating system to send the calling process a signal with signal code value when data is available on path. If data is already pending, a signal is sent immediately. Otherwise, control returns to the calling program and the signal is sent when data arrives.

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

#define TRUE 1
#define FALSE 0

#define GOT_CHAR 2001
short dataready;     /* flag to show that signal was received */

/* sighand – signal handling routine for this process */
sighand(signal)
register int signal;
{
     switch(signal) {
           /* ^E or ^C? */
           case 2:
           case 3:
               _errmsg(0,“termination signal received\n”);
               exit(signal);
          /* Signal we’re looking for? */

          case GOT_CHAR:
               dataready = TRUE;
               break;
          /* Anything else? */
          default:
               _errmsg(0,“unknown signal received ==> %d\n”,signal);
               exit(1);
     }
}

main()
{
     char buffer[256];            /* buffer for typed–in string */

     intercept(sighand);          /* set up signal handler */

     printf(“Enter a string:\n”); /* prompt user */

     /* call timed_read, returns TRUE if no timeout, –1 if timeout */
     if (timed_read(buffer) == TRUE)
          printf(“Entered string = %s\n”,buffer);
```

```
     else
          printf("\nType faster next time!\n");
}
int timed_read(buffer)
register char *buffer;
{
     char c = '\0';            /* 1 character buffer for read */
     short timeout = FALSE;    /* flag to note timeout occurred on read */
     int pos = 0;              /* position holder in buffer */

     /* loop until <return> entered or timeout occurs */
     while ( (c != '\n')  &&  (timeout == FALSE) ) {
          sigmask(1);            /* mask signals for signal setup */
          _ss_ssig(0,GOT_CHAR);  /* set up to have signal sent */
          sleep(10);             /* sleep for 10 seconds or until signal */

/* NOTE: we had to mask signals before doing _ss_ssig() so we did not get the
signal between the time we _ss_ssig()'ed and went to sleep.  */

          /* Now we're awake, determine what happened */
          if (!dataready)
               timeout = TRUE;
          else {
               read(0,&c,1);        /* read the ready byte */
               buffer[pos] = c;     /* put it in the buffer */
               pos++;               /* move our position holder */
               dataready = FALSE;   /* mark data as read */
          }
     }

     /* loop has terminated, figure out why */
     if (timeout)
          return -1;            /* there was a timeout so return -1 */
     else {
          buffer[pos] = '\0';   /* null terminate the string */
          return TRUE;
     }
}
#asm
* C binding for sigmask(value)
sigmask: move.l d1,-(sp)        save d1 on the stack
 move.l d0,d1                   get the passed parameter in the right place
 clr.l d0                       make d0 = 0
 os9 F$SigMask                  make the system call to mask signals
 bcc.s ret                      if no error...
 move.l #-1,d0                  return -1 to user
 move.l d1,errno(a6)            fill errno with error number
ret move.l (sp)+,d1             restore d1 from the stack
 rts                            return to user
#endasm
```

Alarms: Example Program

Compile the following example program with this command:

```
$ cc deton.c
```

The complete source code for the example program is as follows:

```
/*-------------------------------------------------------------------------|
|          Psect Name:deton.c                                              |
|          Function: demonstrate alarm to time out user input              |
|-------------------------------------------------------------------------*/
@_sysedit: equ 1

#include <stdio.h>
#include <errno.h>

#define TIME(secs) ((secs << 8) | 0x80000000)
#define PASSWORD “Ripley”

/*-------------------------------------------------------------------------*/
sighand(sigcode)
{
          /* just ignore the signal */
}
/*-------------------------------------------------------------------------*/
main(argc,argv)
int     argc;
char    **argv;
{
    register int    secs = 0;
    register int    alarm_id;
    register char   *p;
    register char   name[80];


    intercept(sighand);
    while (--argc)
        if (*(p = *(++argv)) == ’-’) {
            if (*(++p) == ’?’)
                printuse();
            else exit(_errmsg(1, “error: unknown option – ’%c’\n”, *p));

        } else if (secs == 0)
                secs = atoi(p);
            else exit(_errmsg(1, “unknown arg – \”%s\“\n”, p));

    secs = secs ? secs : 3;
    printf(“You have %d seconds to terminate self–destruct...\n”, secs);


    /* set alarm to time out user input */
    if ((alarm_id = alm_set(2, TIME(secs))) == –1)
        exit(_errmsg(errno, “can’t set alarm – ”));

    if (gets(name) != 0)
        alm_delete(alarm_id);     /* remove the alarm; it didn’t expire */
    else printf(“\n”);
```

```
    if (_cmpnam(name, PASSWORD, 6) == 0)
        printf("Have a nice day, %s.\n", PASSWORD);
    else printf("ka BOOM\n");

    exit(0);
}

/*-------------------------------------------------------------------------*/
/* printuse() – print help text to standard error                          */
printuse()
{
    fprintf(stderr, "syntax: %s [seconds]\n", _prgname());
    fprintf(stderr, "function: demonstrate use of alarm to time out I/O\n");
    fprintf(stderr, "options: none\n");
    exit(0);
}
```

Events: Example Program

The following program uses a binary semaphore to illustrate the use of events. To execute this example:

1. Type the code into a file called sema1.c.
2. Copy sema1.c to sema2.c.
3. Compile both programs.
4. Run both programs with this command: sema1 & sema2

The program creates an event with an initial value of 1 (free), a wait increment of –1, and a signal increment of 1. Then, the program enters a loop which waits on the event, prints a message, sleeps, and signals the event. After ten times through the loop, the program unlinks itself from the event and deletes the event from the system.

```
#include <stdio.h>
#include <events.h>
#include <errno.h>

char *ev_name = “semaevent”;     /* name of event to be used */
int ev_id;     /* id that will be used to access event */

main()
{
     int count = 0;  /* loop counter */

     /* create or link to the event */
     if ((ev_id = _ev_link(ev_name)) == –1)
          if ((ev_id = _ev_creat(1,–1,1,ev_name)) == –1)
               exit(_errmsg(errno,“error getting access to event – ”));

     while (count++ < 10) {
          /* wait on the event */
          if (_ev_wait(ev_id, 1, 1) == –1)
               exit(_errmsg(errno,“error waiting on the event – ”));

          _errmsg(0,“entering \”critical section\“\n”);

          /* simulate doing something useful */
          sleep(2);

          _errmsg(0,“exiting \”critical section\“\n”);

          /* signal event (leaving critical section) */
         if (_ev_signal(ev_id, 0) == –1)
               exit(_errmsg(errno,“error signalling the event – ”));

          /* simulate doing something other than critical section */
          sleep(1);

     }
     /* unlink from event */
```

```
        if (_ev_unlink(ev_id) == –1)
             exit(_errmsg(errno,“error unlinking from event – ”));

        /* delete event from system if this was the last process to unlink from it */
        if (_ev_delete(ev_name) == –1 && errno != E_EVBUSY)
             exit(_errmsg(errno,“error deleting event from system – ”));

        _errmsg(0,“terminating normally\n”);
    }
```

C Trap Handler

Use the following makefile to make the example C trap handler and test programs:

```
# makefile – Used to make the example C trap handler and test program.

CFLAGS = –sqgixt=/dd
RDIR   = RELS
TRAP   = ctrap
TEST   = traptst

# Dependencies for making the entire example.

ctrap.example: $(TRAP) $(TEST)
    touch ctrap.example

# Dependencies for making the ctrap trap handler.

$(TRAP): tstart.r $(TRAP).r
    chd $(RDIR);\
    l68 tstart.r $(TRAP).r –l=/dd/lib/cio.l –l=/dd/lib/clib.l –l=/dd/lib/sys.l\
                –o=$(TRAP) –g

# Dependencies for making the traptst test program.

$(TEST): $(TEST).r

$(TEST).r: $(TEST).c
    cc –gim=2k $(TEST).c –r=$(RDIR)
```

The complete source for the C trap handler startup routines (tstart.a) is as follows:

```
****************************************
*
* tstart.a – C trap handler startup routines.
*
            nam     tstart C trap handler interface
            use     /dd/defs/oskdefs.d

*SYSTRAP    equ     1       define if trap should execute in system state

MaxParams   equ     20      maximum number of “C” style parameters allowed

        ifdef   SYSTRAP
AttrRevs    set     (ReEnt+SupStat)<<8  (system state)
        else
AttrRevs    set     (ReEnt)<<8          (user state)
        endc

TypeLang    set     (TrapLib<<8)+Objct
            psect   traphand,TypeLang,AttrRevs,0,0,TrapEnt
            dc.l    TrapInit
            dc.l    TrapTerm
******************************
* Subroutine TrapInit
*   Trap handler initialization entry point
```

```
*
* Passed: d0.w  = User Trap number (1–15)
*         d1.l  = (optional) additional static storage
*         d2–d7 = caller’s registers at time of trap
*         (a0)  = trap handler module name pointer
*         (a1)  = trap handler execution entry point
*         (a2)  = trap module pointer
*         a3–a5 = caller’s registers at time of trap
*         (a6)  = trap handler static storage pointer
*         (a7)  = trap init stack frame pointer
*
* Returns: d0.l = “C” trapinit return value
*          (a0) = updated trap handler name pointer
*          (a1) = trap handler execution entry point
*          (a2) = trap module pointer
*          cc   = carry set, d1.w = error code if error
*          Other values returned are dependent on the trap handler
*
* The user stack looks like this:
*           .-------------------------.
*        +8 |    caller’s return PC   |
*           |------------+------------|
*        +4 |    0000    |    0000    |
*           |------------|------------|
*           |   caller’s a6 register  |
*   (usp)->  -------------------------
*
* NOTE: In system state, (a7)=system stack pointer.  This has a reasonable
*       amount of stack space (~1K).  No assumptions about where it is
*       should be made.
TrapInit:   bra     TrapEnt     call “C” trap handler (with func. code zero)

*******************************
* Subroutine TrapEnt
*   User Trap entry point
*
* Passed: d0–d7 = caller’s registers
*         a0–a5 = caller’s registers
*         (a6)  = trap handler static storage pointer
*         (a7)  = trap entry stack frame pointer
*         usp   = undisturbed user stack (in system state)
*
* Returns: cc   = carry set, d1.w=error code if error
*          Other values returned are dependent on the trap handler
*
* The system stack looks like this:
*           .-------------------------.
*        +8 |   caller’s return PC    |
*           |-------------+-----------
*        +6 |   vector #  |
*           |-------------|
*        +4 |  func code  |
*           |-------------+-----------.
*           |  caller’s (a6) register |
*   (a7)->   -------------------------
```

```
            org     0           stack offset definitions
S_CParams   do.l    MaxParams
S_a0        do.l    1           caller's a0 regS_a1        do.l    1
caller's a1 reg
S_a6        do.l    1           caller's a6 reg
S_func      do.w    1           trap function code
S_vect      do.w    1           user trap exception offset
S_cleanup   equ     .
S_pc        do.l    1           return pc

TrapEnt:    movem.l a0-a1,-(a7)         save regs
            lea     -MaxParams*4(a7),a7 allocate parameter space
            lea     S_CParams(a7),a1    ptr to C parameter area

        ifdef   SYSTRAP
            move    usp,a0      caller's parameters are on user stack ptr
            adda.l  #12,a0      above two rts pc's
        else
            lea     S_pc+16(a7),a0  caller's remaining C parameters ptr
        endc

            moveq   #MaxParams-1,d1 number of (potential) parameters
Trap10      move.l  (a0)+,(a1)+     copy caller's params from user stack
            dbra    d1,Trap10
            moveq   #0,d0           sweep reg
            move.w  S_func(a7),d0   1st param = func
            move.l  S_a6(a7),d1     2nd param = caller's (a6)
            bsr     ctrap           execute C traphandler
Trap90      movea.l S_a6(a7),a6     restore caller's a6
            lea     S_cleanup(a7),a7    discard scratch
            rts                     return to user program

*******************************
* Subroutine TrapTerm
*   Terminate trap handler servicing.
*
* As of this release (OS-9 V2.3) the trap termination entry point
* is never called by the OS-9 kernel.  Documentation details will
* be available when a working implementation exists.

TrapTerm:   move.w  #1<<8+199,d1    never called; so if it gets here...
            OS9     F$Exit          crash program (Error 001:199)

            ends
```

The complete source for the example C trap handler library (ctrap.c) is as follows:

```
/*****************************************
 *
 * ctrap.c – Example C trap handler library.
 *
 * ctrap(func, a6, p1, p2, ...)
 */

int ctrap(func, a6, p1, p2, p3, p4)
register int func;              /* trap function code */
char *a6;                       /* caller's static storage base */
unsigned int p1, p2, p3, p4;    /* caller's parameters */
{
    register int result;

    switch(func)
    {
        case  0 :   result = 0;         break;  /* tlink call */
        case '+':   result = p1 + p2;   break;
        case '–':   result = p1 – p2;   break;
        case '*':   result = p1 * p2;   break;
        case '/':   result = p1 / p2;   break;
        case '&':   result = p1 & p2;   break;
        case '|':   result = p1 | p2;   break;
        case '^':   result = p1 ^ p2;   break;
        case '>':   result = p1 >> p2;  break;
        case '<':   result = p1 << p2;  break;
        default :   result = –1;        break;
    }
    return (result);
}
```

The complete source for traptst.c, which calls the ctrap handler, is as follows:

```
/*****************************************
 *
 * traptst.c – Calls the "ctrap" trap handler.
 *
 */

main()
{
    int   i, n;
    int   x = 22;
    int   y = 5;
    int   trapnum = 6;
    char *operator = "+–*/&|^<>?";

    printf("tlink: %d\n", tlink(trapnum, "ctrap"));

    n = strlen (operator);
    for (i = 0; i < n; ++i)
        printf("tcall(%d %c %d) = %d\n", x, operator[i], y,
            tcall(trapnum, operator[i], x, y));
}
```

```
/* bindings for tlink, tcall */
/*****************************************************************/
/* tlink(trapnum, trapname) – link to trap handler               */
/* int trapnum;             user trap number (1–15)              */
/* char *trapname;          name of trap module (NULL to unlink) */

#asm
tlink:      link    a5,#0
            movem.l a0–a2,–(a7)     save regs
            movea.l d1,a0           copy ptr to trap handler name
            moveq   #0,d1           no memory override
            OS9     F$TLink         link to trap handler
            bcc.s   tlink99         exit if no error
            move.l  d1,errno(a6)    save error number for caller
            moveq   #–1,d0          return error status
tlink99     movem.l (a7)+,a0–a2     restore regs
            unlk    a5
            rts
#endasm

/*****************************************************************/
/* tcall(trapnum, func, param1, param2, ...) – call trap handler */
/* int trapnum;             user trap number (1–15)              */
/* short func;              trap function number                 */
/* other parameters may be ints or pointers                      */

#asm
TRAP        equ     $4e40       user trap(0) opcode
RTS         equ     $4e75       rts opcode
            vsect
trapinst    ds.w    2
rtsinst     ds.w    1
            ends

tcall:      link    a5,#0
            tst.l   d0              valid trap number?
            beq.s   paramerr        abort if not
            cmp.l   #15,d0          valid trap number?
            bhi.s   paramerr
            add.w   #TRAP,d0
            movem.w d0–d1,trapinst(a6)  build usr trap instruction
            move.w  #RTS,rtsinst(a6)    set rts instruction
            moveq.l #0,d0           flush instruction cache
            os9     F$CCtl          ignore error
            jsr     trapinst(a6)    execute trap call
            bcc.s   tcall99         exit if no error
            move.l  d1,errno(a6)    save error number
            bra.s   tcallerr        abort

paramerr    move.l  #E$Param,errno(a6)
tcallerr    moveq   #–1,d0
tcall99
            unlk    a5
            rts
#endasm
```

RBF Device Descriptor

```
Microware OS–9/68020 Resident Macro Assembler V2.9  90/12/07  15:29  Page     1
 ../io/d0.a
D0 Device Descriptor – Device Descriptor for Floppy disk controller
00001                       nam      D0 Device Descriptor
00002                       use      defsfile
00001
00002                       use      ../DEFS/oskdefs.d
00001                       opt      –l
00003                       use      ./systype.d
00001 * System Definitions for MVME147 System
00002 *
00003                       opt      –l
00004
00005
00003                       use      ../io/rbfdesc.a
00001
00002                       ttl      Device Descriptor for Floppy disk controller
00003
00045  0000000e Edition     equ      14              current edition number
00046
00047 * PD_DNS values
00048  00000000 Single      equ      0               FM encoded media
00049  00000001 Double      equ       1              MFM encoded media/double–track
                                                     density
00050  00000002 Quad        equ      1<<1            Quad track density
00051  00000004 Octal       equ      1<<2            Octal track density
00052
00053 * PD_TYP values
00054 * Note: For pre–V2.4 Five/Eight defines the disk size, rotational
00055 *       speed and data transfer rate.  From V2.4 the physical size
00056 *       is defined in bits 4 – 1, and PD_Rate defines the rotational
00057 *       speed and data transfer rate.
00058
00059 * floppy disk definitions
00060  00000000 Five         equ      0<<0            drive is 5 1/4″
00061  00000001 Eight        equ      1<<0            drive is 8″
00062  00000000 SizeOld       equ      0<<1           size/speed defined by
                                                     bit 0 value (pre–V2.4)
00063  00000002 Size8        equ      1<<1            physical size is 8″
00064  00000004 Size5        equ      2<<1            physical size is 5 1/4″
00065  00000006 Size3        equ      3<<1            physical size is 3 1/2″
00066
00067 * hard disk definitions
00068  00000040 HRemov       equ      1<<6            hard disk is removable
00069  00000080 Hard         equ      1<<7            hard disk media
00070
00071 * PD_Rate values
00072 * Note: V2.4 drivers should derive the disk data transfer rate and
00073 *       rotational speed from this field if PD_TYP, bits 4 – 1 are
00074 *       non–zero.  If not, then PD_TYP, bit 0 infers these.
00075  00000000 rpm300      equ      0               rotational speed is 300 rpm
00076  00000001 rpm360      equ      1               rotational speed is 360 rpm
00077  00000002 rpm600      equ      2               rotational speed is 600 rpm
00078  00000000 xfr125K     equ      0<<4            transfer rate is 125K bits/sec
```

```
00079  00000010 xfr250K    equ      1<<4           transfer rate is 250K bits/sec

00080  00000020 xrf300K    equ      2<<4           transfer rate is 300K bits/sec
00081  00000030 xfr500K    equ      3<<4           transfer rate is 500K bits/sec
00082  00000040 xfr1M      equ      4<<4           transfer rate is 1M bits/sec
00083  00000050 xfr2M      equ      5<<4           transfer rate is 2M bits/sec
00084  00000060 xfr5M      equ      6<<4           transfer rate is 5M bits/sec
00085
00086 * PD_VFY values
00087  00000001 ON          equ      1              “no-verify” ON
00088  00000000 OFF         equ      0              “no-verify” OFF
                                                    (i.e. verify is ON!)
00089
00090 * macro parameter #6 definitions (drive type)
00091
00092  00000001 d877        equ      1              single density 8”
00093  00000004 dd877       equ      4              double density 8”
00094  00000002 d540        equ      2              single density 5 1/4” 40 trk
00095  00000005 dd540       equ      5              double density 5 1/4” 40 trk
00096  00000003 d580        equ      3              single density 5 1/4” 80 trk
00097  00000006 dd580       equ      6              double density 5 1/4” 80 trk
00098  00000007 ramdisk     equ      7              volatile ram disk
00099  00000008 nvramdisk   equ      8              non-volatile ram disk
00100  00000009 uv580       equ      9              universal 5 1/4” 80 track
00101  0000000a autosize    equ      10             autosize device (SS_DSize tells
media size)
00102  0000000b dd380       equ      11             double density 3 1/2”, 80 trk
00103  0000000c uv380       equ      12             universal 3 1/2” 80 track
00104  0000000d hd580       equ      13             double density 5 1/4”
                                                      80 track ’8” image’
00105  0000000e ed380       equ      14             double density 3 1/2”
                                                      80 track, 4M byte unformatted
00106  0000000f hd577       equ      15             double density 5 1/4”
                                                      77 track ’8” image’
00107  00000010 uv577       equ      16             universal 5 1/4” ’8” image’
00108  00000011 uv877       equ      17             universal 8”
00109
00110  00000003 Density     set      BitDns+(TrkDns<<1)
00111  00000024 DiskType    set      DiskKind+(DnsTrk0<<5)
00112
00113  00000f00 TypeLang    set      (Devic<<8)+0
00114  00008000 Attr_Rev    set      (ReEnt<<8)+0
00115
00116                       psect    RBFDesc,TypeLang,Attr_Rev,Edition,0,0
00117
00118 0000 fffe            dc.l     Port           port address
00119 0004   45            dc.b     Vector         auto-vector trap assignment
00120 0005   04            dc.b     IRQLevel       IRQ hardware interrupt level
00121 0006   05            dc.b     Priority       irq polling priority
00122 0007   a7            dc.b     Mode           device mode capabilities
00123 0008 0048            dc.w     FileMgr        file manager name offset
00124 000a 004c            dc.w     DevDrv         device driver name offset
00125 000c 0053            dc.w     DevCon         (reserved)
00126 000e 0000            dc.w     0,0,0,0        reserved
00127 0016 0030            dc.w     OptLen
00128
```

```
00129 * Default Parameters
00130           OptTbl
00131 0018=  00            dc.b     DT_RBF         device type
00132 0019   02            dc.b     DrvNum         drive number
00133 001a   03            dc.b     StepRate       step rate
00134 001b   24            dc.b     DiskType       type of disk 8"/5 1/4"/Hard/etc
00135 001c   03            dc.b     Density        Bit Density and track density
00136 001d   00            dc.b     0              reserved
00137 001e 004f            dc.w     Cylnders-TrkOffs number of logical cylinders
00138 0020   02            dc.b     Heads          Number of Sides (Floppy)
                                                   Heads(Hard Disk)
00139 0021   00            dc.b     NoVerify       OFF = disk verify ON = no verify
00140 0022 0010            dc.w     SectTrk        default sectors/track
00141 0024 0010            dc.w     SectTrk0       default sectors/track track 0
00142 0026 0008            dc.w     SegAlloc       segment allocation size
00143 0028   04            dc.b     Intrleav       sector interleave factor
00144 0029   00            dc.b     DMAMode        DMA mode (driver dependant)
00145 002a   01            dc.b     TrkOffs        track base offset (first
                                                   accessable track)
00146 002b   01            dc.b     SectOffs       sector base offset
                                                   (starting physical sector number)
00147 002c 0100            dc.w     SectSize       # of bytes/sector
00148 002e 0002            dc.w     Control        control byte
00149 0030   07            dc.b     Trys           number of retrys
                                                   0 = no retrys/error correction
00150 0031   02            dc.b     ScsiLun        scsi logical unit number
00151 0032 0000            dc.w     WrtPrecomp     write precomp cylinder
00152 0034 0000            dc.w     RedWrtCrnt     reduce write current cylinder
00153 0036 0000            dc.w     ParkCyl        cylinder to park head
                                                   for hard disk
00154 0038 0000            dc.l     LSNOffset      logical sector offset
00155 003c 0050            dc.w     TotalCyls      total cylinders on drive
00156 003e   06            dc.b     CtrlrID        scsi controller id
00157 003f   10            dc.b     Rates          data-transfer rate &
                                                   rotational speed
00158 0040 0000            dc.l     ScsiOpts       scsi option flags
00159 0044 0000            dc.l     MaxCount-1     maximum byte count
                                                   passable to driver
00160  00000030 OptLen     equ      *-OptTbl
00161
00162 0048 5242 FileMgr    dc.b     "RBF",0        Random block file manager

00274           DiskKind   set      Size5   five inch disk
00275           Cylnders   set      80     number of (physical) tracks
00276           BitDns     set      Double MFM recording
00277           Rates      set      xfr250K+rpm300
00278           DnsTrk0    set      Double MFM track 0
00279           TrkDns     set      Double 96tpi
00280           SectTrk    set      16     sectors/track (except trk 0, side 0)
00281           SectTrk0   set      16     sectors/track, track 0, side 0
00282           SectOffs   set      1      physical sector start = 1
00283           TrkOffs    set      1      track 0 not used
00284           TotalCyls  set      Cylnders number of actual cylinders on disk
00384
00385 ****************
```

```
00386 * Descriptor Defaults
00387  000000a7 Mode       set      Dir_+ISize_+Exec_+Updat_
00388  00000000 BitDns     set      Single
00389  00000002 Heads      set      2
00390  00000002 StepRate   set      2
00391  00000003 Intrleav   set      3
00392  00000000 NoVerify   set      OFF
00393  00000000 DnsTrk0    set      Single
00394  00000000 DMAMode    set      0              non dma device
00395  00000008 SegAlloc   set      8              minimum segment allocation size
00396  00000000 TrkOffs    set      0
00397  00000000 SectOffs   set      0
00398  00000100 SectSize   set      256            default sector size 256 bytes.
00399  00000000 WrtPrecomp set      0              no write precomp
00400  00000000 RedWrtCrnt set      0              no reduced write current
00401  00000000 ParkCyl    set      0              where to park the head for
                                                   hard disk
00402  00000000 ScsiLun    set      0              scsi logical unit number
00403  00000000 CtrlrID    set      0              controller id
00404  00000000 LSNOffset  set      0              logical sector offset for scsi
                                                   hard disks
00405  00000000 TotalCyls  set      0              number of actual cylinders
                                                   on disk
00406
00407 * scsi options flag definitions
00408
00409  00000001 scsi_atn   set       1<<0           assert ATN supported
00410  00000002 scsi_target set      1<<1           target mode supported
00411  00000004 scsi_synchr set      1<<2           synchronous transfers supported
00412  00000008 scsi_parity set      1<<3           enable SCSI parity
00413
00414  00000000 ScsiOpts   set      0              scsi options flags (default)
00415
00416 * device control word definitions
00417
00418  00000000 FmtEnabl   set      0<<0           enable formatting
00419  00000001 FmtDsabl   set      1<<0           disable formatting
00420  00000000 MultDsabl  set      0<<1           disable multi-sectors
00421  00000002 MultEnabl  set      1<<1           enable multi-sectors
00422  00000000 StabDsabl  set      0<<2           device doesn't have stable id
00423  00000004 StabEnabl  set      1<<2           device has stable id
00424  00000000 AutoDsabl  set      0<<3           device size from device
                                                   descriptor
00425  00000008 AutoEnabl  set      1<<3           device tells size via SS_DSize
00426  00000000 FTrkDsabl  set      0<<4           device can't format a single track
00427  00000010 FTrkEnabl  set      1<<4           device can format a single track
00428  00000000 Control    set      0              descriptor control word (default)
00429
00430  00000007 Trys       set      7              number of Trys
00431  00010000 MaxCount   set      65536          default maximum transfer count of
driver (16-bit)
00432  00000000 Rates      set      0              default transfer-rate & rotational
speed
00433
00434 * end of file
00435
```

```
00004  00000000 DrvNum     set      0

00005                       DiskD0
00006                       RBFDesc  SCSIBase,SCSIVect,SCSILevel,5,rb5400,uv580
00011 004c 7262+DevDrv      dc.b     “rb5400”,0     driver module name

00107  00000004+DiskKind    set      Size5          five inch disk
00108  00000050+Cylnders    set      80             number of (physical) tracks
00109  00000001+BitDns      set      Double         MFM recording
00110  00000010+Rates       set      xfr250K+rpm300
00111  00000001+DnsTrk0     set      Double         MFM track 0
00112  00000001+TrkDns      set      Double         96tpi
00113  00000010+SectTrk     set      16             sectors/track
                                                   (except trk 0, side 0)
00114  00000010+SectTrk0    set      16             sectors/track, track 0, side 0
00115  00000001+SectOffs    set      1              physical sector start = 1
00116  00000001+TrkOffs     set      1              track 0 not used
00117  00000050+TotalCyls   set      Cylnders       number of actual cylinders on disk

00119
00213  00000002+DrvNum      set      2              logical device number
00214  00000003+StepRate    set      3              6ms step rate
00215  00000004+Intrleav    set      4
00216  00000001+SectOffs    set      fd_base
00217  0000ff01+MaxCount    set      SectSize*255+1 practical max byte–count to pass
00218  00000002+Control     set      FmtEnabl+MultEnabl
                                                    format enable,multi–sector i/o
00219  00000002+ScsiLun     set      OMTI_FD_LUN    Logical unit number on controller
00220  00000006+CtrlrID     set      OMTI_TargID    scsi id of controller
00221 0053 7363+DevCon      dc.b     “scsi147”,0    low–level driver module
00222  0000005c             ends
```

SCF Device Descriptor

```
Microware OS-9/68000 Resident Macro Assembler V1.6 86/11/04  Page 1 term.a
Term – 68000 Term device descriptor module
00001                       nam     Term
00002                       ttl     68000          Term device desc. module
00003                       use     defsfile
00004
00005
00006
00007
00008                       use     ../io/scfdesc.a
00011
00012  00000004 Edition     equ     4              current edition number
00013
00014  00000f00 TypeLang    set     (Devic<<8)+0
00015  00008000 Attr_Rev    set     (ReEnt<<8)+0
00016                       psect   ScfDesc,TypeLang,Attr_Rev,Edition,0,0 00017
00018 0000 00fe             dc.l    Port           port address
00019 0004   70             dc.b    Vector         auto-vector trap assignment
00020 0005   02             dc.b    IRQLevel       IRQ hardware interrupt lev.
00021 0006   53             dc.b    Priority       irq polling priority
00022 0007   23             dc.b    Mode           Device mode capabilities
00023 0008 0034             dc.w    FileMgr        file manager name offset
00024 000a 0038             dc.w    DevDrv         device driver name offset
00025 000c=0000             dc.w    DevCon         device constant's offset
00026 000e 0000             dc.w    0,0,0,0        reserved
00027 0016 001c             dc.w    OptSiz         option byte count
00028
00029 * Default Parameters
00030           Options
00031 *                                                              default
00032 *                              name           function          value
00033 *                             --------       -----------------  -------
00034 0018   00             dc.b      DT_SCF       device type          SCF
00035 0019   00             dc.b      upclock      upcase lock          OFF
00036 001a   01             dc.b      bsb          backspace=BS,SP,BS   ON
00037 001b   00             dc.b      linedel      line del/bsp line    OFF
00038 001c   01             dc.b      autoecho     full duplex          ON
00039 001d   01             dc.b      autolf       auto line feed       ON
00040 001e   00             dc.b      eolnulls     null count           0
00041 001f   00             dc.b      pagpause     end of page pause    OFF
00042 0020   18             dc.b      pagsize      lines per page       24
00043 0021   08             dc.b      C$Bsp        backspace char       ^H
00044 0022   18             dc.b      C$Del        delete line char     ^X
00045 0023   0D             dc.b      C$CR         end of record char   <cr>
00046 0024   1B             dc.b      C$EOF        end of file char     ESC
00047 0025   04             dc.b      C$Rprt       reprint line char    ^D
00048 0026   01             dc.b      C$Rpet       dup last line char   ^A
00049 0027   17             dc.b      C$Paus       pause char           ^W
00050 0028   03             dc.b      C$Intr       Keyboard Interrupt char  ^C
00051 0029   05             dc.b      C$Quit       Keyboard Quit char   ^E
00052 002a   08             dc.b      C$Bsp        backspace echo char  ^H
00053 002b   07             dc.b      C$Bell       line overflow char   ^G
00054 002c   00             dc.b      Parity       stop bits and parity     none
00055 002d   0E             dc.b      BaudRate     bits/char and baud rate  none
```

```
00056 002e=0000           dc.w     EchoNam      offset of echo device    none
00057 0030   11           dc.b     C$XOn        Transmit Enable char     ^Q
00058 0031   13           dc.b     C$XOff       Transmit Disable char    ^S
00059 0032   09           dc.b     C$Tab        tab character
00060 0033   00           dc.b     tabsize      tab column size
00061  0000001c OptSiz     equ      *-Options
00062
00063 0034 5363 FileMgr    dc.b     "Scf",0      file manager
00080
00081  00000023 Mode       set      ISize_+Updat_  default dev mode capabil.
00082
00010  00000040           ends
00011
Errors: 00000
Memory used: 31k
Elapsed time: 26 second(s)
```

SBF Device Descriptor

```
Microware OS-9/68000 Resident Macro Assembler V1.9  90/12/07  15:30  Page     1
 mt0_sbviper.a
MT0 Device Descriptor - Device Descriptor for Tape controller
00001                       nam      MT0 Device Descriptor
00002
00003                       use      defsfile
00001
00002                       use      ../DEFS/oskdefs.d
00001                       opt      -l
00003                       use      ./systype.d
00001 * System Definitions for MVME147 System
00002 *
00003                       opt      -l
00004
00005
00004                       use      ../DEFS/sbfdesc.d
00001                       ttl      Device Descriptor for Tape controller
00002
00027  00000005 Edition     equ      5              current edition number
00028
00029
00030  00000f00 TypeLang    set      (Devic<<8)+0
00031  00008000 Attr_Rev    set      (ReEnt<<8)+0
00032                       psect    SBFDesc,TypeLang,Attr_Rev,Edition,0,0
00033
00034 0000 fffe            dc.l     Port           port address
00035 0004   45            dc.b     Vector         vector trap assignment
00036 0005   04            dc.b     IRQLevel       IRQ hardware interrupt level
00037 0006   05            dc.b     Priority       irq polling priority
00038 0007   67            dc.b     Mode           device mode capabilities
00039 0008 002c            dc.w     FileMgr        file manager name offset
00040 000a 0030            dc.w     DevDrv         device driver name offset
00041 000c 0038            dc.w     DevCon         device constants offset
00042 000e 0000            dc.w     0,0,0,0        reserved
00043 0016 0014            dc.w     OptLen
00044
00045 * Default Parameters
00046           OptTbl
00047 0018   03            dc.b     3              DT_SBF device type
00048 0019   00            dc.b     DrvNum         drive number
00049 001a   00            dc.b     0              reserved
00050 001b   08            dc.b     NumBlks        maximum number of block buffers
00051 001c 0000            dc.l     BlkSize        block size
00052 0020 03e8            dc.w     DrvPrior       driver process priority
00053 0022   00            dc.b     SBFFlags       file manager flags
00054 0023   00            dc.b     DrivFlag       driver flags
00055 0024 0000            dc.w     DMAMode        DMA type/usage
00056 0026   04            dc.b     ScsiID         controller ID on SCSI bus
00057 0027   00            dc.b     ScsiLUN        tape drive LUN on controller
00058 0028 0000            dc.l     ScsiOpts       scsi option flags
00059  00000014 OptLen      equ      *-OptTbl
00060
00061 002c 5342 FileMgr     dc.b     "SBF",0        Random block file manager
00062
```

```
00063
00064           SBFDesc    macro
00065
00066           Port       equ      \1 Port address
00067           Vector     equ      \2 autovector number
00068           IRQLevel   equ      \3 hardware interrupt level
00069           Priority   equ      \4 polling priority
00070           DevDrv     dc.b     "\5",0 driver module name
00071                      ifgt     \#-5 standard device setup requested?
00072
00073
00074                      endc
00075                      endm
00076
00077 ****************
00078 * Descriptor Defaults

MT0 Device Descriptor - Device Descriptor for Tape controller
00079  00000067 Mode       set      Share_+ISize_+Exec_+Updat_
00080 *DevCon   set 0
00081  00000000 Speed      set      0              driver defined
00082  00000002 NumBlks    set      2
00083  00002000 BlkSize    set      0x2000
00084  00000100 DrvPrior   set      256
00085  00000000 SBFFlags   set      0
00086  00000000 DrivFlag   set      0
00087  00000000 DMAMode    set      0              driver defined
00088  00000000 ScsiID     set      0
00089  00000000 ScsiLUN    set      0
00090
00091 * scsi options flag definitions
00092
00093  00000001 scsi_atn   set      1<<0           assert ATN supported
00094  00000002 scsi_target set      1<<1           target mode supported
00095  00000004 scsi_synchr set      1<<2           synchronous transfers supported
00096  00000008 scsi_parity set      1<<3           enable SCSI parity
00097  00000000 ScsiOpts   set      0              scsi options flags
00098
00005
00006 * user changable device descriptor defaults
00007
00008  00000000 DrvNum     set      0              drive number
00009  00000008 NumBlks    set      8              number of blocks (buffered)
00010  00008000 BlkSize    set      0x8000         LOGICAL block size (MUST be multiple
of 512)
00011  000003e8 DrvPrior   set      1000           priority of "sbf" process
00012
00013  00000045 IRQVect    set      69             vector to use
00014  00000004 IRQLev     set      4              hardware interrupt level
00015  00000005 IRQPrior   set      5              polling priority (within vector)
00016 00017  00000004 ScsiID     set      4              scsi id of viper
00018  00000000 ScsiLUN    set      0              viper lun always 0.00019
00023
00024 ********************
00025 *
00026 *  SBFDesc macro:  port, vector, IRQlevel, IRQpriority, driver name.
```

```
00027 *
00028                       SBFDesc  PortAddr,IRQVect,IRQLev,IRQPrior,“sbviper”
00036 0038 7363 DevCon      dc.b     “scsi147”,0
00037
00038  00000001 ScsiOpts    set      scsi_atn       disconnect supported
00039  00000040             ends
00040
```

Appendix **B**

Path Descriptors and Device Descriptors

Introduction

This appendix includes the device descriptor initialization table definitions and path descriptor option tables for RBF, SCF, SBF, and PIPEMAN type devices. Refer to Appendix A for RBF, SCF, and SBF example device descriptors.

RBF Device Descriptor Modules

This section describes the definitions of the initialization table contained in device descriptor modules for RBF-type devices. The table immediately follows the standard device descriptor module header fields (see Chapter 3 for full descriptions). Figure B.1 shows a graphic representation of the table. The size of the table is defined in the M$Opt field.

Name:	Description:
PD_DTP	**Device type** This field is set to one for RBF devices. (0=SCF, 1=RBF, 2=PIPE, 3=SBF, 4=NET)
PD_DRV	**Drive number** Use this field to associate a one-byte logical integer with each drive that a driver/controller handles. Number each controller's drives 0 to n–1 (n is the maximum number of drives the controller can handle and is set into V_NDRV by the driver's INIT routine). This number defines which drive table the driver and RBF access for this device. RBF uses this number to set up the drive table pointer (PD_DTB). Prior to initializing PD_DTB, RBF verifies that PD_DRV is valid for the driver by checking for a value less than V_NDRV in the driver's static storage. If not valid, RBF aborts the path open and returns an error. On simple hardware, this logical drive number is often the same as the physical drive number.
PD_STP	**Step rate** This field contains a code that sets the drive's head-stepping rate. To reduce access time, set the step rate to the fastest value of which the drive is capable. For floppy disks, the following codes are commonly used: Step Code 5" Disks 8" Disks 0 30ms 15ms 1 20ms 10ms 2 12ms 6ms 3 6ms 3ms For hard disks, the value in this field is usually driver dependent.

Name:	Description:
PD_TYP	**Disk type** Defines the physical type of the disk, and indicates the revision level of the descriptor. If bit 7 = 0, floppy disk parameters are described in bits 0-6: bit 0: 0 = 5 1/4" floppy disk (pre-Version 2.4 of OS-9) 1 = 8" floppy disk (pre-Version 2.4 of OS-9) bits 1-3: 0 = (pre-Version 2.4 descriptor) Bit 0 describes type/rates. 1 = 8" physical size 2 = 5 1/4" physical size 3 = 3 1/2" physical size 4-7: Reserved bit 4: Reserved bit 5: 0 = Track 0, side 0, single density 1 = Track 0, side 0, double density bit 6: Reserved If bit 7 = 1, hard disk parameters are described in bits 0-6: bits 0-5: Reserved bit 6: 0 = Fixed hard disk 1 = Removable hard disk
PD_DNS	**Disk density *** The hardware density capabilities of a floppy disk drive: bit 0: 0 = Single bit density (FM) 1 = Double bit density (MFM) bit 1: 1 = Double track density (96 TPI/135 TPI) bit 2: 1 = Quad track density (192 TPI) bit 3: 1 = Octal track density (384 TPI)
PD_CYL	**Number of cylinders (tracks) *** The logical number of cylinders per disk. Format uses this value, PD_SID, and PD_SCT to determine the size of the drive. PD_CYL is often the same as the physical cylinder count (PD_TotCyls), but can be smaller if using partitioned drives (PD_LSNOffs) or track offsetting (PD_TOffs). If the drive is an autosize drive (PD_Cntl), format ignores this field.
PD_SID	**Heads or sides *** The number of heads for a hard disk (Heads) or the number of surfaces for a floppy disk (Sides). If the drive is an autosize drive (PD_Cntl), format ignores this field.
PD_VFY	**Verify flag** Indicates whether or not to verify write operations. 0 = verify disk write 1 = no verification NOTE: Write verify operations are generally performed on floppy disks. They are not generally performed on hard disks because of the lower soft error rate of hard disks.
PD_SCT	**Default sectors/track*** The number of sectors per track. If the drive is an autosize drive (PD_Cntl), format ignores this field.
PD_T0S	**Default sectors/track (track 0) *** The number of sectors per track for track 0. This may be different than PD_SCT (depending on specific disk format). If the drive is an autosize drive (PD_Cntl), format ignores this field.

Name:	Description:
PD_SAS	**Segment allocation size** The default minimum number of sectors to be allocated when a file is expanded. Typically, this is set to the number of sectors on the media track (for example, 8 for floppy disks, 32 for hard disks), but can be adjusted to suit the requirements of the system.
PD_ILV	**Sector interleave factor *** The sequential arrangement of sectors on a disk (for example, 1, 2, 3... or 1, 3, 5...). For example, if the interleave factor is 2, the sectors are arranged by 2's (1, 3, 5...) starting at the base sector (see PD_SOffs). NOTE: Optimized interleaving can drastically improve I/O throughput. NOTE: PD_ILV is typically only used when the media is formatted, as format uses this field to determine the default interleave. However, when the media format occurs (I$SetStat, SS_WTrk call), the desired interleave is passed in the parameters of the call.
PD_TFM	**DMA (Direct Memory Access) transfer mode** The mode of transfer for DMA access, if the driver is capable of handling different DMA modes. Use of this field is driver dependent.
PD_TOffs	**Track base offset *** The offset to the first accessible physical track number. Track 0 is not always used as the base track because it is often a different density.
PD_SOffs	**Sector base offset *** The offset to the first accessible physical sector number on a track. Sector 0 is not always the base sector.
PD_SSize	**Sector size** Indicates the physical sector size in bytes. The default sector size is 256. Depending upon whether the driver supports non-256 byte logical sector sizes (that is, a variable sector size driver), the field is used as follows: • Variable sector size driver If the driver supports variable logical sector sizes, RBF inspects this value during a path open (specifically, after the driver returns "no error" on the SS_VarSect GetStat call) and uses this value as the *logical* sector size of the media. This value is then copied into PD_SctSiz of the path descriptor options section, so that application programs can know the logical sector size of the media, if required. RBF supports logical sector sizes from 256 bytes to 32,768 bytes, in integral binary multiples (256, 512, 1024, etc.). During the SS_VarSect call, the driver can validate or update this field (or the media itself) according to the driver's conventions. These typically are: • If the driver can dynamically determine the media's sector size, and PD_SSize is passed in as 0, the driver updates this field according to the current media setting. • If the driver can dynamically set the media's sector size, and PD_SSize is passed in as a non-zero value, the driver sets the media to the value in PD_SSize (this is typical when re-formatting the media). • If the driver cannot dynamically determine or set the media sector size, it usually validates PD_SSize against the supported sector sizes, and returns an error (E$SectSiz) if PD_SSize contains an invalid value. • Non-variable sector size driver If the driver does not support variable logical sector sizes (that is, logical sector size is fixed at 256 bytes), RBF ignores PD_SSize. In this case, PD_SSize can be used to support deblocking drivers that support various physical sector sizes. NOTE: A non-variable sector sized driver is defined as a driver which returns the E$UnkSvc error for GetStat (SS_VarSect).

Name:	Description:
PD_Cntl	**Device control word** Indicates options that reflect the capabilities of the device. You may set these options, as follows: bit 0: 0 = Format enable 1 = Format inhibit bit 1: 0 = Single-Sector I/O 1 = Multi-Sector I/O capable bit 2: 0 = Device has non-stable ID 1 = Device has stable ID bit 3: 0 = Device size determined from descriptor values 1 = Device size obtained by SS_DSize GetStat call bit 4: 0 = Device cannot format a single track 1 = Device can format a single track bits 5-15: Reserved
PD_Trys	**Number of tries** Indicates whether a driver should try to access the disk again before returning an error. Depending upon the driver in use, this field may be implemented as a flag or a retry counter: Value Flag Counter 0 retry ON default number of retries 1 retry OFF no retries other retry ON specified number of retries Drivers that work with controllers that have error correcting functions (for example, E.C.C. on hard disks) should treat this field as a flag so they can set the controller's error correction/retry functions accordingly. When formatting media, especially hard disks, the format-enabled descriptor should set this field to one (retry OFF) to ensure that marginal media sections are marked out of the media free space.
PD_LUN	**Logical unit number of SCSI drive** Used in the SCSI command block to identify the logical unit on the SCSI controller. To eliminate allocation of unused drive tables in the driver static storage, this number may be different from PD_DRV. PD_DRV indicates the logical number of the drive to the driver, that is, the drive table to use. PD_LUN is the physical drive number on the controller.
PD_WPC	**First cylinder to use write precompensation** The cylinder to begin write precompensation.
PD_RWR	**First cylinder to use reduced write current** The cylinder to begin reduced write current.
PD_Park	**Cylinder used to park head** The cylinder at which to park the hard disk's head when the drive is shut down. Parking is usually done on hard disks when they are shipped or moved and is implemented by the SS_SQD SetStat to the driver.
PD_LSNOffs	**Logical sector offset** The offset to use when accessing a partitioned drive. The driver adds this value to the logical block address passed by RBF prior to determining the physical block address on the media. Typically, using PD_LSNOffs is mutually exclusive to using PD_TOffs.
PD_TotCyls	**Total cylinders on device** The actual number of physical cylinders on a drive. It is used by the driver to correctly initialize the controller/drive. PD_TotCyls is typically used for physical initialization of a drive that is partitioned or has PD_TOffs set to a non-zero value. In this case, PD_CYL denotes the *logical* number of cylinders of the drive. If PD_TotCyls is zero, the driver should determine the physical cylinder count by using the sum of PD_CYL and PD_TOffs.

Name:	Description:
PD_CtrlrID	**SCSI controller ID** The ID number of the SCSI controller attached to the drive. The driver uses this number to communicate with the controller.
PD_ScsiOpt	**SCSI driver options flags** The SCSI device options and operation modes. It is the driver's responsibility to use or reject these values, as applicable. bit 0: 0 = ATN not asserted (no disconnect allowed) 1 = ATN asserted (disconnect allowed) bit 1: 0 = Device cannot operate as a target 1 = Device can operate as a target bit 2: 0 = Asynchronous data transfer 1 = Synchronous data transfer bit 3: 0 = Parity off 1 = Parity on All other bits are reserved.
PD_Rate	**Data transfer/rotational rate** The data transfer rate and rotational speed of the floppy media. Note that this field is normally used only when the physical size field (PD_TYP, bits 1-3) is non-zero. bits 0-3: Rotational speed 0 = 300 RPM 1 = 360 RPM 2 = 600 RPM All other values are reserved. bits 4-7: Data transfer rate 0 = 125K bits/sec 1 = 250K bits/sec 2 = 300K bits/sec 3 = 500K bits/sec 4 = 1M bits/sec 5 = 2M bits/sec 6 = 5M bits/sec All other values are reserved.
PD_MaxCnt	**Maximum transfer count** The maximum byte count that the driver can transfer in one call. If this field is 0, RBF defaults to the value of $ffff (65,535).
* These parameters are format specific.	

Important: *Offset* refers to the location of a module field, relative to the starting address of the static storage area. Offsets are resolved in assembly code by using the names shown here and linking the module with the relocatable library, sys.l or usr.l.

Figure B.1
Initialization Table for RBF Device Descriptor Modules

Device descriptor offset:	Path descriptor label:	Description:
$48	PD_DTP	Device Class
$49	PD_DRV	Drive Number
$4A	PD_STP	Step Rate
$4B	PD_TYP	Device Type
$4C	PD_DNS	Density
$4D		Reserved
$4E	PD_CYL	Number of Cylinders
$50	PD_SID	Number of Heads/Sides
$51	PD_VFY	Disk Write Verification
$52	PD_SCT	Default Sectors/Track
$54	PD_T0S	Default Sectors/Track 0
$56	PD_SAS	Segment Allocation Size
$58	PD_ILV	Sector Interleave Factor
$59	PD_TFM	DMA Transfer Mode
$5A	PD_TOffs	Track Base Offset
$5B	PD_SOffs	Sector Base Offset
$5C	PD_SSize	Sector Size (in bytes)
$5E	PD_Cntl	Control Word
$60	PD_Trys	Number of Tries
$61	PD_LUN	SCSI Unit Number of Drive
$62	PD_WPC	Cylinder to Begin Write Precompensation
$64	PD_RWR	Cylinder to Begin Reduced Write Current
$66	PD_Park	Cylinder to Park Disk Head
$68	PD_LSNOffs	Logical Sector Offset
$6C	PD_TotCyls	Number of Cylinders On Device
$6E	PD_CtrlrID	SCSI Controller ID
$6F	PD_Rate	Data transfer/Disk Rotation Rates
$70	PD_ScsiOpt	SCSI Driver Options Flags
$74	PD_MaxCnt	Maximum Transfer Count

RBF Definitions of the Path Descriptor

The first 26 fields of the path options section (PD_OPT) of the RBF path descriptor are copied directly from the device descriptor standard initialization table. All of the values in this table may be examined using I$GetStt by applications using the SS_Opt code. Some of the values may be changed using I$SetStt; some are protected by the file manager to prevent inappropriate changes. You can update the following fields using GetStat and SetStat system calls:

PD_STP	PD_TYP	PD_DNS
PD_CYL	PD_SID	PD_VFY
PD_SCT	PD_TOS	PD_SAS

All other fields are read-only. The RBF path descriptor option table is shown on the following page.

Refer to the previous section on RBF device descriptors for descriptions of the first 26 fields. The last five fields contain information provided by RBF:

Name:	Description:
PD_ATT	**File attributes** (D S PE PW PR E W R) The file's attributes are defined as follows: bit 0: Set if owner read. bit 1: Set if owner write. bit 2: Set if owner execute. bit 3: Set if public read. bit 4: Set if public write. bit 5: Set if public execute. bit 6: Set if only one user at a time can open the file. bit 7: Set if directory file.
PD_FD	**File descriptor** The LSN (Logical Sector Number) of the file's file descriptor is written here.
PD_DFD	**Directory file descriptor** The LSN of the file's directory file descriptor is written here.
PD_DCP	**File's directory entry pointer** The current position of the file's entry in its directory.
PD_DVT	**Device table pointer (copy)** The address of the device table entry associated with the path.
PD_SctSiz	**Logical sector size** The logical sector size of the device associated with the path. If this is 0, assume a size of 256 bytes.
PD_NAME	**File name**

Important: In the following chart, **offset** refers to the location of a path descriptor field relative to the starting address of the path descriptor. Path descriptor offsets are resolved in assembly code by using the names shown here and linking with the relocatable library: sys.l or usr.l.

Figure B.2
Option Table for RBF Path Descriptor

Offset:	Name:	Description:
$80	PD_DTP	Device Class
$81	PD_DRV	Drive Number
$82	PD_STP	Step Rate
$83	PD_TYP	Device Type
$84	PD_DNS	Density
$85		Reserved
$86	PD_CYL	Number of Cylinders
$88	PD_SID	Number of Heads/Sides
$89	PD_VFY	Disk Write Verification
$8A	PD_SCT	Default Sectors/Track
$8C	PD_TOS	Default Sectors/Track 0
$8E	PD_SAS	Segment Allocation Size
$90	PD_ILV	Sector Interleave Factor
$91	PD_TFM	DMA Transfer Mode
$92	PD_TOffs	Track Base Offset
$93	PD_SOffs	Sector Base Offset
$94	PD_SSize	Sector Size (in bytes)
$96	PD_Cntl	Control Word
$98	PD_Trys	Number of Tries
$99	PD_LUN	SCSI Unit Number of Drive
$9A	PD_WPC	Cylinder to Begin Write Precompensation
$9C	PD_RWR	Cylinder to Begin Reduced Write Current
$9E	PD_Park	Cylinder to Park Disk Head
$A0	PD_LSNOffs	Logical Sector Offset
$A4	PD_TotCyls	Number of Cylinders On Device
$A6	PD_CtrlrID	SCSI Controller ID
$A7	PD_Rate	Data Transfer/Rotational Rates
$A8	PD_ScsiOpt	SCSI Driver Option Flag
$AC	PD_MaxCnt	Maximum Transfer Count
$B0		Reserved
$B5	PD_ATT	File Attributes
$B6	PD_FD	File Descriptor
$BA	PD_DFD	Directory File Descriptor
$BE	PD_DCP	File's Directory Entry Pointer
$C2	PD_DVT	Device Table Pointer (copy)
$C6		Reserved
$C8	PD_SctSiz	Logical Sector Size
$CC		Reserved
$E0	PD_NAME	File Name

SCF Device Descriptor Modules

Device descriptor modules for SCF-type devices contain the device address and an initialization table which defines initial values for the I/O editing features, as listed below. The initialization table immediately follows the standard device descriptor module header fields (see Chapter 3 for full descriptions). The size of the table is defined in the M$Opt field. The initialization table is graphically shown in Figure B.3 and the following table.

Important: You can change or disable most of these special editing functions by changing the corresponding control character in the path descriptor. You can do this with the I$SetStt service request or the tmode utility. A permanent solution may be to change the corresponding control character value in the device descriptor module. You can easily change the device descriptors with the xmode utility.

Name:	Description:
PD_DTP	**Device type** Set to zero for SCF devices. (0=SCF, 1=RBF, 2=PIPE, 3=SBF, 4=NET)
PD_UPC	**Letter case** If PD_UPC is not equal to zero, input or output characters in the range “a..z” are made “A..Z”.
PD_BSO	**Destructive backspace** If PD_BSO is zero when a backspace character is input, SCF echoes PD_BSE (backspace echo character). If PD_BSO is non-zero, SCF echoes PD_BSE, space, PD_BSE.
PD_DLO	**Delete** If PD_DLO is zero, SCF deletes by backspace-erasing over the line. If PD_DLO is not zero, SCF deletes by echoing a carriage return/line-feed.
PD_EKO	**Echo** If PD_EKO is not zero, all input bytes are echoed, except undefined control characters, which are printed as periods. If PD_EKO is zero, input characters are not echoed.
PD_ALF	**Automatic line feed** If PD_ALF is not zero, line-feeds automatically follow carriage returns.
PD_NUL	**End of line null count** Indicates the number of NULL padding bytes to send after a carriage return/line-feed character.
PD_PAU	**End of page pause** If PD_PAU is not zero, an auto page pause occurs upon reaching a full screen of output. See PD_PAG for setting page length.
PD_PAG	**Page length** Contains the number of lines per screen (or page).
PD_BSP	**Backspace “input” character** Indicates the input character recognized as backspace. See PD_BSE and PD_BSO.
PD_DEL	**Delete line character** Indicates the input character recognized as the delete line function. See PD_DLO.

Name:	Description:
PD_EOR	**End of record character** Defines the last character on each line entered (I$Read, I$ReadLn). An output line is terminated (I$Writln) when this character is sent. Normally PD_EOR should be set to $0D. **WARNING:** If PD_EOR is set to zero, SCF's I$ReadLn will *never* terminate, unless an EOF or error occurs.
PD_EOF	**End of file character** This field defines the end-of-file character. SCF returns an end-of-file error on I$Read or I$ReadLn if this is the first (and only) character input.
PD_RPR	**Reprint line character** If this character is input, SCF (I$ReadLn) reprints the current input line. A carriage return is also inserted in the input buffer for PD_DUP (see below) to make correcting typing errors more convenient.
PD_DUP	**Duplicate last line character** If this character is input, SCF (I$ReadLn) duplicates whatever is in the input buffer through the first PD_EOR character. Normally, this is the previous line typed.
PD_PSC	**Pause character** If this character is typed during output, output is suspended before the next end-of-line. This also deletes any "type ahead" input for I$ReadLn.
PD_INT	**Keyboard interrupt character** If this character is input, SCF sends a keyboard interrupt signal to the last user of this path. It terminates the current I/O request (if any) with an error identical to the keyboard interrupt signal code. PD_INT is normally set to a control-C character.
PD_QUT	**Keyboard abort character** If this character is input, SCF sends a keyboard abort signal to the last user of this path. It terminates the current I/O request (if any) with an error code identical to the keyboard abort signal code. PD_QUT is normally set to a control-E character.
PD_BSE	**Backspace "output" character (echo character)** This field indicates the backspace character to echo when PD_BSP is input. See PD_BSP and PD_BSO.
PD_OVF	**Line overflow character** If I$ReadLn has satisfied its input byte count, SCF ignores any further input characters until an end-of-record character (PD_EOR) is received. It echoes the PD_OVF character for each byte ignored. PD_OVF is usually set to the terminal's bell character.
PD_PAR	**Parity code, number of stop bits and bits/character** Bits zero and one indicate the parity as follows: 0 = no parity 1 = odd parity 3 = even parity Bits two and three indicate the number of bits per character as follows: 0 = 8 bits/character 1 = 7 bits/character 2 = 6 bits/character 3 = 5 bits/character Bits four and five indicate the number of stop bits as follows: 0 = 1 stop bit 1 = 1 1/2 stop bits 2 = 2 stop bits Bits six and seven are reserved.

Name:	Description:
PD_BAU	**Software adjustable baud rate** This one-byte field indicates the baud rate as follows: 0 = 50 baud 6 = 600 baud C = 4800 baud 1 = 75 baud 7 = 1200 baud D = 7200 baud 2 = 110 baud 8 = 1800 baud E = 9600 baud 3 = 134.5 baud 9 = 2000 baud F = 19200 baud 4 = 150 baud A = 2400 baud 10 = 38400 baud 5 = 300 baud B = 3600 baud FF = External
PD_D2P	**Offset to output device descriptor name string** SCF sends output to the device named in this string. Input comes from the device named by the M$PDev field. This permits two separate devices (a keyboard and video display) to be one logical device. Usually PD_D2P refers to the name of the same device descriptor in which it appears.
PD_XON	**X-ON character** See PD_XOFF below.
PD_XOFF	**X_OFF character** The X-ON and X-OFF characters are used to support software handshaking. Output from a SCF device is halted immediately when PD_XOFF is received and does not resume until PD_XON is received. This allows the distant end to control its incoming data stream. Input to a SCF device is controlled by the driver. If the input FIFO is nearly full, the driver sends PD_XOFF to the distant end to halt input. When the FIFO has been emptied sufficiently, the driver resumes input by sending the PD_XON character. This allows the driver to control its incoming data stream. NOTE: When software handshaking is enabled, the driver consumes the PD_XON and PD_XOFF characters itself.
PD_Tab	**Tab character** In I$WritLn calls, SCF expands this character into spaces to make tab stops at the column intervals specified by PD_Tabs. NOTE: SCF does not know the effect of tab characters on particular terminals. Tab characters may expand incorrectly if they are sent directly to the terminal.
PD_Tabs	**Tab field size** See PD_Tab.

Important: Offset refers to the location of a module field, relative to the starting address of the module. Module offsets are resolved in assembly code by using the names shown here and linking the module with the relocatable library: sys.l or usr.l.

Figure B.3
Device Descriptor Initialization Table

Device descriptor offset:	Path descriptor label:	Description:
$48	PD_DTP	Device Type
$49	PD_UPC	Upper Case Lock
$4A	PD_BSO	Backspace Option
$4B	PD_DLO	Delete Line Character
$4C	PD_EKO	Echo
$4D	PD_ALF	Automatic Line Feed
$4E	PD_NUL	End Of Line Null Count
$4F	PD_PAU	End Of Page Pause
$50	PD_PAG	Page Length
$51	PD_BSP	Backspace Input Character
$52	PD_DEL	Delete Line Character
$53	PD_EOR	End Of Record Character
$54	PD_EOF	End Of File Character
$55	PD_RPR	Reprint Line Character
$56	PD_DUP	Duplicate Line Character
$57	PD_PSC	Pause Character
$58	PD_INT	Keyboard Interrupt Character
$59	PD_QUT	Keyboard Abort Character
$5A	PD_BSE	Backspace Output
$5B	PD_OVF	Line Overflow Character (bell)
$5C	PD_PAR	Parity Code, # of Stop Bits, and # of Bits/Character
$5D	PD_BAU	Adjustable Baud Rate
$5E	PD_D2P	Offset To Output Device Name
$60	PD_XON	X-ON Character
$61	PD_XOFF	X-OFF Character
$62	PD_TAB	Tab Character
$63	PD_TABS	Tab Column Width

SCF Definitions of the Path Descriptor

The first 27 fields of the path options section (PD_OPT) of the SCF path descriptor are copied directly from the SCF device descriptor initialization table. The table is shown on the following page.

You can examine or change the fields with the I$GetStt and I$SetStt service requests or the tmode and xmode utilities.

You may disable the SCF editing functions by setting the corresponding control character value to zero. For example, if you set PD_INT to zero, there is no “keyboard interrupt” character.

Important: Full definitions for the fields copied from the device descriptor are available in the previous section. The additional path descriptor fields are defined below:

Name:	Description:
PD_TBL	**Device table entry** A user-visible copy of the device table entry for the device.
PD_COL	**Current column** The current column position of the cursor.
PD_ERR	**Most recent error status** The most recent I/O error status.

Important: Offset refers to the location of a module field, relative to the starting address of the module. Module offsets are resolved in assembly code by using the names shown here and linking the module with the relocatable library: sys.l or usr.l.

Figure B.4
Path Descriptor Module Option Table for I/O Editing

Offset:	Name:	Description:
$80	PD_DTP	Device Type
$81	PD_UPC	Upper Case Lock
$82	PD_BSO	Backspace Option
$83	PD_DLO	Delete Line Character
$84	PD_EKO	Echo
$85	PD_ALF	Automatic Line Feed
$86	PD_NUL	End Of Line Null Count
$87	PD_PAU	End Of Page Pause
$88	PD_PAG	Page Length
$89	PD_BSP	Backspace Input Character
$8A	PD_DEL	Delete Line Character
$8B	PD_EOR	End Of Record Character
$8C	PD_EOF	End Of File Character
$8D	PD_RPR	Reprint Line Character
$8E	PD_DUP	Duplicate Line Character
$8F	PD_PSC	Pause Character
$90	PD_INT	Keyboard Interrupt Character
$91	PD_QUT	Keyboard Abort Character
$92	PD_BSE	Backspace Output
$93	PD_OVF	Line Overflow Character (bell)
$94	PD_PAR	Parity Code, # of Stop Bits, and # of Bits/Character
$95	PD_BAU	Adjustable Baud Rate
$96	PD_D2P	Offset To Output Device Name
$98	PD_XON	X-ON Character
$99	PD_XOFF	X-OFF Character
$9A	PD_TAB	Tab Character
$9B	PD_TABS	Tab Column Width
$9C	PD_TBL	Device Table Entry
$A0	PD_Col	Current Column
$A2	PD_Err	Most Recent Error Status
$A3		Reserved

SBF Device Descriptor Modules

This section describes the definitions of the initialization table contained in device descriptor modules for SBF devices. The initialization table immediately follows the standard device descriptor module header fields (see Chapter 3 for full descriptions). A graphic representation of the table is shown in Figure B.5. The size of the table is defined in the M$Opt field.

Figure B.5
Initialization Table for SBF Device Descriptor Module

Device descriptor offset:	Path descriptor label:	Description:
$48	PD_DTP	Device Type
$49	PD_TDrv	Tape Drive Number
$4A	PD_SBF	Reserved
$4B	PD_NumBlk	Maximum Number of Blocks to Allocate
$4C	PD_BlkSiz	Logical Block Size
$50	PD_Prior	Driver Process Priority
$52	PD_SBFFlags	SBF Path Flags
$53	PD_DrivFlag	Driver Flags
$54	PD_DMAMode	Direct Memory Access Mode
$56	PD_ScsiID	SCSI Controller ID
$57	PD_ScsiLUN	LUN on SCSI Controller
$58	PD_ScsiOpts	SCSI Options Flags

Important: In this table the offset values are the device descriptor offsets, while the labels are the path descriptor offsets. To correctly access these offsets in a device descriptor using the path descriptor labels, make the following adjustment: (M$DTyp – PD_OPT).

For example, to access the tape drive number in a device descriptor, use the following value: PD_TDrv + (M$DTyp – PD_OPT). To access the tape drive number in the path descriptor, use PD_TDrv. Module offsets are resolved in assembly code by using the names shown here and linking with the relocatable library: sys.l or usr.l.

Name:	Description:
PD_DTP	**Device class** This field is set to three for SBF devices. (0=SCF, 1=RBF, 2=PIPE, 3=SBF, 4=NET)
PD_TDrv	**Tape drive number** This is used to associate a one-byte integer with each drive that a controller will handle. If using dedicated (for example, non-SCSI bus) controllers, this field usually defines both the *logical* and *physical* drive number of the tape drive. If using tape drives connected to SCSI controllers, this number defines the *logical* number of the tape drive to the device driver. The *physical* controller ID and LUN are specified by the PD_ScsiID and PD_ScsiLUN fields. Each controller's drives should be numbered 0 to n–1 (n is the maximum number of drives the controller can handle). This number also defines how many drive tables are required by the driver and SBF. SBF verifies this number against SBF_NDRV prior to calling the driver.

Name:	Description:
PD_NumBlk	**Number of buffers/blocks used for buffering** Specifies the maximum number of buffers to be allocated by SBF for use by the auxiliary process in buffered I/O. If this field is set to 0, unbuffered I/O is specified.
PD_BlkSiz	**Logical block size used for I/O** Specifies the size of the buffer to be allocated by SBF. This buffer size is used when allocating multiple buffers used in buffered I/O. Unless the driver manages partial physical blocks, this size should be an integer multiple of the physical tape block size.
PD_Prior	**Driver process priority** The priority at which SBF's auxiliary process will run. This value is used during initialization. Changing this value after initialization has no effect.
PD_SBFFlags	**SBF path flags** Specifies the actions that SBF takes when the path is closed. You can update this field using GetStat/SetStat (SS_Opt). SBF supports the following flag definitions: bit 0: (f_rest_b) 0 = No rewind on close. 1 = Rewind on close. bit 1: (f_offl_b) 0 = Do not put drive off-line on close. 1 = Put drive off-line on close. bit 2: (f_eras_b) 0 = Do not erase to end-of-tape on close. 1 = Erase to end-of-tape on close.
PD_DrivFlag	**Driver flags** This field is available for use by the device driver. NOTE: References to these flags are often made using the PD_Flags offset (defined in sys.l and usr.l). This reference is equivalent to PD_SBFFlags. References to PD_DrivFlag should use a value of PD_Flags + 1.
PD_DMAMode	**Direct memory access mode** This field is hardware specific. If available, you can use this word to specify the DMA Mode of the driver.
PD_ScsiID	**SCSI controller ID** This is the ID number of the SCSI controller attached to the device. The driver uses this number when communicating with the controller.
PD_ScsiLUN	**Logical unit number of SCSI device** This number is the value to use in the SCSI command block to identify the logical unit on the SCSI controller. This number may be different from PD_TDrv to eliminate allocation of unused drive table storage. PD_TDrv indicates the logical number of the drive to the driver and SBF (drive table to use). PD_ScsiLUN is the physical drive number on the controller.
PD_ScsiOpts	**SCSI driver options flags** This field allows SCSI device options and operation modes to be specified. It is the driver's responsibility to use or reject these if applicable: bit 0: 0 = ATN not asserted (no disconnects allowed). 1 = ATN asserted (disconnects allowed). bit 1: 0 = Device cannot operate as a target. 1 = Device can operate as a target. bit 2: 0 = asynchronous data transfers. 1 = synchronous data transfers. bit 3: 0 = parity off. 1 = parity on. All other bits are reserved.

SBF Definitions of the Path Descriptor

The reserved section (PD_OPT) of the path descriptor used by SBF is copied directly from the initialization table of the device descriptor. The following table is provided to show the offsets used in the path descriptor. For a full explanation of the path descriptor fields, refer to the previous pages.

Offset:	Name:	Description:
$80	PD_DTP	Device Type
$81	PD_TDrv	Tape Drive Number
$82	PD_SBF	Reserved
$83	PD_NumBlk	Maximum Number of Blocks to Allocate
$84	PD_BlkSiz	Logical Block Size
$88	PD_Prior	Driver Process Priority
$8A	PD_SBFFlags*	SBF Path Flags
$8B	PD_DrivFlag*	Driver Flags
$8C	PD_DMAMode	Direct Memory Access Mode
$8E	PD_ScsiID	SCSI Controller ID
$8F	PD_ScsiLUN	LUN on SCSI controller
$90	PD_ScsiOpts	SCSI Options Flags

* References to these flags are often made using the PD_Flags offset (defined in sys.l and usr.l). This reference is equivalent to PD_SBFFlags. References to PD_DrivFlag should use a value of PD_Flags + 1.

Important: Offset refers to the location of a path descriptor field relative to the starting address of the path descriptor. Path descriptor offsets are resolved in assembly code by using the names shown here and linking the module with the relocatable library: sys.l or usr.l.

Pipeman Definitions of the Path Descriptor

The table shown below describes the option section (PD_OPT) of the path descriptor used by pipeman.

Important: Offset refers to the location of a module field, relative to the starting address of the module. Module offsets are resolved in assembly code by using the names shown here and linking the module with the relocatable library: sys.l or usr.l.

Table B.A
Path Descriptor PD_OPT for PIPEMAN

Offset:	Name:	Description:
$80	DV_DTP	Device type
$81		Reserved
$82	PD_BufSz	Default pipe buffer size
$86	PD_IOBuf	Reserved I/O buffer
$ED	PD_Name	Pipe file name

Name:	Description:
DV_DTP	**Device type** This field is set to two for PIPE devices. (0 = SCF, 1 = RBF, 2 = PIPE, 3 = SBF, 4 = NET)
PD_BufSz	**Default pipe buffer size** Contains the default size of the FIFO buffer used by the pipe. If no default size is specified and no size is specified when creating the pipe, PD_IOBuf is used.
PD_IOBuf	**Reserved I/O buffer** This contains the small I/O buffer to be used by the pipe if no other buffer is specified.
PD_Name	**Pipe file name (if any)**

Appendix C

OS-9 System Calls

OS-9 System Call Descriptions

You use system calls to communicate between the OS-9 operating system and assembly language level programs. There are three general categories of system calls:

- user-state
- I/O
- system-state

All system calls have a mnemonic name for easy reference. User and system state functions start with F$. I/O related functions begin with I$. The mnemonic names are defined in the relocatable library file usr.l or sys.l. You should link these files with your programs.

The OS-9 I/O system calls are simpler to use than in many other operating systems. This is because the calling program does not have to allocate and set up file control blocks, sector buffers, etc. Instead, OS-9 returns a path number word when a file/device is opened. You can use this path number in subsequent I/O requests to identify the file/device until the path is closed. OS-9 internally allocates and maintains its own data structures, you never have to deal with them.

System state system calls are privileged and can only execute while OS-9 is in system state (when it is processing another service request, executing a file manager, device driver, etc.). System state functions are included in this manual primarily for the benefit of those programmers who are writing device drivers and other system-level applications. For a full description of system state and its uses, refer to Chapter 2 of the OS-9 Technical Overview.

System calls are performed by loading the MPU registers with the appropriate parameters and executing a Trap #0 instruction, immediately followed by a constant word (the request code). Function results (if any) are returned in the MPU registers after OS-9 has processed the service request. All system calls use a standard convention for reporting errors; if an error occurred, the carry bit of the condition code register is set and register d1.w contains an appropriate error code, permitting a BCS or BCC instruction immediately following the system call to branch on error/no error.

Here is an example system call for the Close service request:

```
MOVE.W  Pathnum (a6),d0
TRAP    #0
DC.W    I$Close
BCS.S   Error
```

Using the assembler's OS9 directive simplifies the call:

```
MOVE.W  Pathnum (a6),d0
OS9     I$Close
BCS.S   Error
```

Some system calls generate errors themselves; these are listed as POSSIBLE ERRORS. If the returned error code does not match any of the given possible errors, then it was probably returned by another system call made by the main call.

The SEE ALSO listing for each service request shows related service requests and/or chapters that may yield more information about the request.

In the system call descriptions which follow, registers not explicitly specified as input or output parameters are not altered. Strings passed as parameters are normally terminated by a null byte.

F$Alarm

Set Alarm Clock

ASM Call

```
OS9 F$Alarm
```

Input

```
d0.l = Alarm ID (or zero)
d1.w = Alarm function code
d2.l = Signal code
d3.l = Time interval (or time)
d4.l = Date (when using absolute time)
```

Output

```
d0.l = Alarm ID
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

F$Alarm creates an asynchronous software alarm clock timer. The timer sends a signal to the calling process when the specified time period has elapsed. A process may have multiple alarm requests pending.

The time interval is the number of system clock ticks (or 256ths of a second) to wait before an alarm signal is sent. If the high order bit is set, the low 31 bits are interpreted as 256ths of a second.

Important: All times are rounded up to the nearest clock tick.

The system automatically deletes a process's pending alarms when the process dies.

The alarm function code selects one of the several related alarm functions. Not all input parameters are always needed; each function is described in detail in the following pages.

OS-9 supports the following function codes:

A$Delete	Remove a pending alarm request
A$Set	Send a signal after specified time interval
A$Cycle	Send a signal at specified time intervals
A$AtDate	Send a signal at Gregorian date/time
A$AtJul	Send a signal at Julian date/time

See Also

`F$Alarm` System State Call

Possible Errors

`E$UnkSvc, E$Param, E$MemFul, E$NoRAM, and E$BPAddr.`

A$Delete

Remove a Pending Alarm Request

Input

```
d0.l = Alarm ID (or zero)
d1.w = A$Delete function code
```

Output

None

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`A$Delete` removes a cyclic alarm, or any alarm that has not expired. If zero is passed as the alarm ID, all pending alarm requests are removed.

A$Set

Send a Signal After a Specified Time Interval

Input

```
d0.l = Reserved, must be zero
d1.w = A$Set function code
d2.w = Signal code
d3.l = Time Interval
```

Output

```
d0.l = Alarm ID
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`A$Set` sends one signal after the specified time interval has elapsed. The time interval may be specified in system clock ticks, or 256ths of a second.

A$Cycle

Send a Signal Every N Ticks/Seconds

Input

```
d0.l = reserved, must be zero
d1.w = A$Cycle function code
d2.l = signal code
d3.l = time interval (N)
```

Output

```
d0.l = Alarm ID
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`A$Cycle` is similar to the A$Set function, except that the alarm is reset after it is sent, to provide a recurring periodic signal.

A$AtDate

Send a Signal at Gregorian Date/Time

Input

```
d0.l = Reserved, must be zero
d1.w = A$AtDate function code
d2.l = Signal code
d3.l = Time (00hhmmss)
d4.l = Date (YYYYMMDD)
```

Output

```
d0.l = Alarm ID
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`A$AtDate` sends a signal to the caller at a specific date and time.

Important: `A$AtDate` only allows you to specify time to the nearest second. However, it does adjust if the system's date and time have changed (via F$STime). The alarm signal is sent anytime the system date/time becomes greater than or equal to the alarm time.

A$AtJul

Send a Signal at Julian Date/Time

Input

```
d0.l = Reserved, must be zero
d1.w = A$AtDate or A$AtJul function code
d2.l = Signal code
d3.l = Time (seconds after midnight)
d4.l = Date (Julian day number)
```

Output

```
d0.l = Alarm ID
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`A$AtJul` sends a signal to the caller at a specific Julian date and time.

Important: `A$AtJul` only allows you to specify time to the nearest second. However, it does adjust if the system's date and time have changed (via F$STime). The alarm signal is sent anytime the system date/time becomes greater than or equal to the alarm time.

F$AllBit

Sends Bits in an Allocation Bit Map

ASM Call

```
OS9 F$AllBit
```

Input

```
d0.w = Bit number of first bit to set
d1.w = Bit count (number of bits to set)
(a0) = Base address of an allocation bit map
```

Output

None

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`F$AllBit` sets bits in the allocation map that were found by F$SchBit, and are now allocated. Bit numbers range from 0 to n–1, where n is the number of bits in the allocation bit map.

In some applications you must allocate and deallocate segments of a fixed resource, such as memory. One convenient way is to set up a map that describes which blocks are available or in use. Each bit in the map represents one block. If the bit is set, the block is in use. If the bit is clear, the block is available. The F$SchBit, F$AllBit, and F$DelBit system calls perform the elementary bitmap operations of finding a free segment, allocating it, and returning it when it is no longer needed.

RBF uses these routines to manage cluster allocation on disks. They are accessible to users because they are occasionally useful.

See Also

`F$SchBit` and `F$DelBit`.

F$CCtl

Cache Control

ASM Call

```
OS9 F$CCtl
```

Input

```
d0.l = desired cache control operation
```

Output

None

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`F$CCtl` performs operations on the system instruction and/or data caches, if there are any.

If d0.l is set to zero, the system instruction and data caches are flushed. Non-super-group, user-state processes may perform this generic operation.

Only system-state processes (for example, device driver) and super-group processes may perform precise operation of F$CCtl. The following bits are defined in d0.l for precise operation:

Bit 0	If set, enables data cache.
Bit 1	If set, disables data cache.
Bit 2	If set, flushes data cache.
Bit 4	If set, enables instruction cache.
Bit 5	If set, disables instruction cache.
Bit 6	If set, flushes instruction cache.

All other bits are reserved. If any reserved bit is set, an E$Param error is returned.

Any program that builds or changes executable code in memory should flush the instruction cache by F$CCtl prior to the execution of the new code. This is necessary because the hardware instruction cache is not updated by data (write) accesses and may therefore contain the unchanged instruction(s). For example, if a subroutine builds an OS-9 system call on its stack, the F$CCtl system call to flush the instruction cache must execute prior to executing the temporary instructions.

Possible Errors

`E$Param`

F$Chain

Load and Execute New Primary Module

ASM Call

```
OS9 F$Chain
```

Input

```
d0.w = desired module type/language (must be
program/object or 0=any)
d1.l = additional memory size
d2.l = parameter size
d3.w = number of I/O paths to copy
d4.w = priority
(a0) = module name ptr
(a1) = parameter ptr
```

Output

```
None: F$Chain does not return to the calling process.
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`F$Chain` executes an entirely new program, but without the overhead of creating a new process. It is similar to a Fork command followed by an EXIT. `F$Chain` effectively resets the calling process's program and data memory areas and begins execution of a new primary module. Open paths are not closed or otherwise affected.

Chain executes as follows:

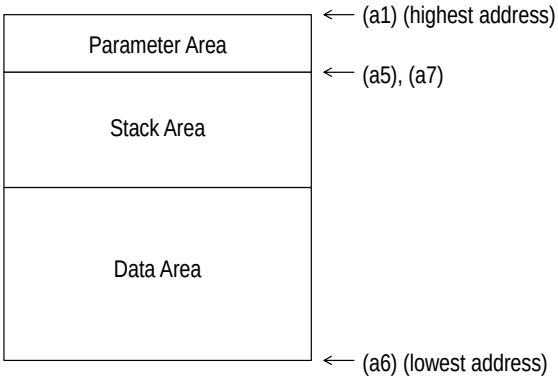
1. The process's old primary module is unlinked.

2. The system parses the name string of the new process's primary module (the program that will be executed). Next, the system module directory is searched to see if a module of the same name and type/language is already in memory. If so, the module is linked. If not, the name string is used as the pathlist of a file which is to be loaded into memory. The first module in this file is linked.

3. The data memory area is reconfigured to the specified size in the new primary module's header.

4. Intercepts and any pending signals are erased.

The diagram below shows how Chain sets up the data memory area and registers for the new module (these are identical to F$Fork).



Registers passed to child process:

Register:	Description:	Remarks:
sr	0000	(a0) = undefined
pc	module entry point	(a1) = top of memory pointer
d0.w	process ID	(a2) = undefined
d1.l	group/user number	(a3) = primary (forked) module
d2.w	priority	pointer
d3.w	number of I/O paths inherited	(a4) = undefined
d4.l	undefined	(a5) = parameter pointer
d5.l	parameter size	(a6) = static storage (data area)
d6.l	total initial memory allocation	base pointer
d7.l	undefined	(a7) = stack pointer (same as a5)

Important: `(a6)` is actually biased by $8000, but this can usually be ignored because the linker biases all data references by –$8000. However, it may be significant to note when debugging programs.

The minimum overall data area size is 256 bytes. Address registers point to even addresses.

See Also

`F$Fork` and `F$Load`.

Caveats

Most errors that occur during the Chain are returned as an exit status to the parent of the process doing the chain.

Possible Errors

`E$NEMod`

F$CmpNam

Compare Two Names

ASM Call

```
OS9 F$CmpNam
```

Input

```
d1.w = Length of pattern string
(a0) = Pointer to pattern string
(a1) = Pointer to target string
```

Output

```
cc = Carry bit clear if the strings match
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`F$CmpNam` compares a target name to a source pattern to determine if they are equal. Upper and lower case are considered to match. Two wild card characters are recognized in the pattern string:

- question mark (?) matches any single character
- asterisk (*) matches any string

The target name must be terminated by a null byte.

Possible Errors

`E$Differ`	The names do not match.
`E$StkOvf`	The pattern is too complex.

F$CpyMem

Copy External Memory

ASM Call

```
OS9 F$CpyMem
```

Input

```
d0.w = process ID of external memory's owner
d1.l = number of bytes to copy
(a0) = address of memory in external process to copy
(a1) = caller's destination buffer pointer
```

Output

None

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`F$CpyMem` copies external memory into your buffer for inspection. You can use F$CpyMem to copy portions of the system's address space. This is especially helpful in examining modules. You can view any memory in the system with F$CpyMem.

See Also

`F$Move`

F$CRC

Generate CRC

ASM Call

```
OS9 F$CRC
```

Input

```
d0.l = Data byte count
d1.l = CRC accumulator
(a0) = Pointer to data
```

Output

```
d1.l = Updated CRC accumulator
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`F$CRC` generates or checks the CRC (cyclic redundancy check) values of sections of memory. Compilers, assemblers, or other module generators use F$CRC to generate a valid module CRC.

If the CRC of a new module is to be generated, the CRC is accumulated over the entire module, excluding the CRC itself. The accumulated CRC is complemented and then stored in the correct position in the module.

You can calculate the CRC starting at the source address over a specified number of bytes. It is not necessary to cover an entire module in one call, since the CRC may be accumulated over several calls. The CRC accumulator must be initialized to $FFFFFFFF before the first F$CRC call for any particular module.

An easier method of checking an existing module's CRC is to perform the calculation on the entire module, including the module CRC. The CRC accumulator contains the CRC constant bytes if the module CRC is correct. The CRC constant is defined in sys.l and usr.l as CRCCon. Its value is $00800FE3.

See Also

OS-9 Technical Overview, Chapter 1, section on CRC.

Caveats

The CRC value is three bytes long, in a four-byte field. To generate a valid module CRC, the caller must include the byte preceding the CRC in the check. This byte must be initialized to zero. For convenience, if a data pointer of zero is passed, the CRC is updated with one zero data byte. `F$CRC` always returns $FF in the most significant byte of d1, so d1.l may be directly stored (after complement) in the last four bytes of a module as the correct CRC.

F$DatMod

Create Data Module

ASM Call

```
OS9 F$DatMod
```

Input

```
d0.l = size of data required (not including header or
CRC)
d1.w = desired attr/revision
d2.w = desired access permission
d3.w = desired type/language (optional)
d4.l = memory color type (optional)
(a0) = module name string ptr
```

Output

```
d0.w = module type/language
d1.w = module attr/revision
(a0) = updated name string ptr
(a1) = module data ptr (’execution’ entry)
(a2) = module header ptr
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`F$DatMod` creates a data module with the specified attribute/revision and clears the data portion of the module. The module is initially created with a valid CRC, and entered into the system module directory. Several processes can communicate with each other using a shared data module.

Be careful not to modify the data module’s header or name string to avoid the possibility of the module becoming unknown to the system.

Caveats

The module created contains at least d0.l usable data bytes, but may be somewhat larger. The module itself will be larger by at least the size of the module header and CRC, and rounded up to the nearest system memory allocation boundary.

See Also

`F$SetCRC` and `F$Move`.

Possible Errors

`E$Differ`	The names do not match.
`E$StkOvf`	The pattern is too complex.

F$DelBit

Deallocate in a Bit Map

ASM Call

```
OS9 F$DelBit
```

Input

```
d0.w = Bit number of first bit to clear
d1.w = Bit count (number of bits to clear)
(a0) = Base address of an allocation bit map
```

Output

None

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`F$DelBit` clears bits in the allocation bit map that were previously allocated and are now free for general use. Bit numbers range from 0 to n–1, where n is the number of bits in the allocation bit map.

See Also

`F$AllBitF$CpyMem` and `F$SchBit`.

F$DExec

Execute Debugged Program

ASM Call

```
OS9 F$DExec
```

Input

```
d0.w = process ID of child to execute
d1.l = number of instructions to execute (0 =
continuous)
d2.w = number of breakpoints in list
(a0) = breakpoint list
register buffer contains child register image
```

Output

```
d0.l = total number of instructions executed so far
d1.l = remaining count not executed
d2.w = exception occurred, if non–zero; exception offset
d3.w = classification word (addr or bus trap only)
d4.l = access address (addr or bus trap only)
d5.w = instruction register (addr or bus trap only)
register buffer updated
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`F$DExec` controls the execution of a suspended child process that has been created by the F$DFork call. The process performing F$DExec is suspended and its debugged child process is executed instead. Once the specified number of instructions are executed, a breakpoint is reached or an unexpected exception occurs, execution terminates, and control returns to the parent process. Thus, the parent and the child processes are never active at the same time.

F$DExec traces every instruction of the child process. It checks for the termination conditions after each instruction. Breakpoints are simply lists of addresses to check and work with ROMed object programs. Consequently, the child process being debugged runs at a slow speed.

If a –1 (hex $FFFFFFFF) is passed in d1.l, F$DExec replaces the instruction at each breakpoint address with an illegal opcode. It then executes the child process at full speed (with the trace bit clear) until a breakpoint is reached or the program terminates. This can save an enormous amount of time, but it is impossible for F$DExec to count the number of executed instructions.

Any OS-9 system calls made by the suspended program are executed at full speed and are considered one logical instruction. The same is true of system-state trap handlers. You cannot debug system-state processes.

The system uses the register buffer passed in the F$DFork call to save and restore the child's registers. Changing the contents of the register buffer alters the child process's registers.

If the child process terminates for any reason, the carry bit is set and returned. Tracing may continue as long as the child process does not perform a F$Exit (even after encountering any normally fatal error). A F$DExit call must be made to return the debugged process's resources (memory).

See Also

`F$DFork` and `F$DExit`.

Caveats

Tracing is allowed through user-state trap handlers, intercept routines, and the F$Chain system call. This is not a problem, but may seem strange at times.

Possible Errors

`E$IPrcID` and `E$PrcAbt`.

F$DExit

Exit Debugged Program

ASM Call

```
OS9 F$DExit
```

Input

```
d0.w = process ID of child to terminate
```

Output

```
cc = carry bit set
d1.w = error code if error
```

Error Output

None

Function

`F$DExit` terminates a suspended child process that was created with the F$DFork system call. To permit post-mortem examination, normal termination by the child process does not release any of its resources.

See Also

`F$Exit`, `F$DFork`, and `F$DExec`.

Possible Errors

`E$IPrcID`

F$DFork

Fork Process Under Control of Debugger

ASM Call

```
OS9 F$DFork
```

Input

```
d0.w = desired module type/revision (0 = any)
d1.l = additional stack space to allocate (if any)
d2.l = parameter size
d3.w = number of I/O paths for child to inherit
d4.w = module priority
(a0) = module name ptr (or pathlist)
(a1) = parameter ptr
(a2) = register buffer: copy of child's
(d0–d7/a0–a7/sr/pc)
```

Output

```
d0.w = child process ID
(a0) = updated past module name string
(a2) = initial image of the child process's registers in buffer
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`F$DFork` is similar to F$Fork, except that F$DFork creates a process whose execution can be closely controlled. The child process is not placed in the active queue but is left in a suspended state. This allows the debugger to control its execution through the special system calls F$DExec and F$DExit. (The child process is created with the trace bit of its status register set and is executed with the F$DExec system call.)

See Also

`F$DExit`, `F$Fork`, and `F$DExec`.

Caveats

A process created by F$DFork does not execute unless it is told to do so. When a process is run, the trace bit is set in the user status register. This causes the system trace exception handler to occur once for each user instruction executed, thus user programs run slowly.

Processes whose primary module is owned by a super-user may only be debugged by a super-user. You cannot debug system-state processes.

F$Event

Create, Manipulate, and Delete Events

ASM Call

```
OS9 F$Event
```

Input

```
d1.w = Event function code
All others are dependent on function code
```

Output

Dependent on function code

Error Output

Dependent on function code

Function

Events are multiple-value semaphores that synchronize concurrent processes which share resources such as files, data modules, and CPU time. `F$Event` provides facilities to create and delete events, to permit processes to link/unlink events and obtain event information, to suspend operation until an event occurs, and for various means of signaling.

An OS-9 event is a 32-byte system global variable maintained by the system. The following fields are included in each event:

Field:	Description:
Event ID	This number and the event's array position are used to create a unique ID.
Event name	This name must be unique and cannot exceed 12 characters.
Event value	This four-byte integer value has a range of two billion.
Wait increment	This value is added to the event value when a process waits for the event. It is set when the event is created and does not change.
Signal increment	This value is added to the event value when the event is signaled. This value is set when the event is created and does not change.
Link Count	This is the event use count.
Next event	This is a pointer to the next process in the event queue. An event queue is circular and includes all processes waiting for the event. Each time the event is signaled, this queue is searched.
Previous event	This is a pointer to the previous process in the event queue.

The following function codes are supported:

Ev$Link	Link to existing event by name
Ev$UnLnk	Unlink event
Ev$Creat	Create new event
Ev$Delet	Delete existing event
Ev$Wait	Wait for event to occur
Ev$WaitR	Wait for relative to occur
Ev$Read	Read event value without waiting
Ev$Info	Return event information
Ev$Pulse	Signal an event occurrence
Ev$Signl	Signal an event occurrence
Ev$Set	Set event variable and signal an event occurrence
Ev$SetR	Set relative event variable; signal an event occurrence

Possible Errors

Dependent on function code

See Also

OS-9 Technical Overview Chapter 4, the section on Events.

Ev$Link

Link to Existing Event by Name

Input

```
(a0) = event name string pointer (max 11 chars)
d1.w = 0  (Ev$Link function code)
```

Output

```
d0.l = event ID number
(a0) = updated past event name
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`Ev$Link` determines the ID number of an existing event. Once an event is linked, all subsequent references are made using the event ID returned. This permits the system to access events quickly, while protecting against programs using invalid or deleted events. The event use count is incremented when an Ev$Link is performed. To keep the use count synchronized properly, perform an Ev$UnLnk when the event will no longer be used.

Possible Errors

`E$BNam`	Name is syntactically incorrect or longer than 11 chars.
`E$EvNF`	Event not found in the event table.

Ev$UnLnk

Unlink Event

Input

```
d0.l = event ID number
d1.w = 1 (Ev$UnLnk function code)
```

Output

None

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`Ev$Unlnk` informs the system that a process will no longer use an event. The event use count is decremented and the event is deleted when the count reaches zero. OS-9 uses this only for error checking.

Possible Errors

`E$EvntID`	ID specified is not a valid active event.

Ev$Creat

Create New Event

Input

```
d0.l = initial event variable value
d1.w = 2 (Ev$Creat function code)
d2.w = auto–increment for Ev$Wait
d3.w = auto–increment for Ev$Signl
(a0) = event name string pointer (max 11–chars)
```

Output

```
d0.l = event ID number
(a0) = updated past event name
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

Events may be created and deleted dynamically as needed. Upon creation, an initial signed value is specified, as well as signed increments to be applied each time the event occurs or is waited for. The event ID number returned is used in subsequent F$Event calls to refer to the event created.

Possible Errors

`E$BNam`	Name is syntactically incorrect or longer than 11 characters.
`E$EvFull`	The event table is full.
`E$EvBusy`	The named event already exists.

Ev$Delet

Delete Existing Event

Input

```
(a0) = event name string pointer (max 11–chars)
d1.w = 3 (Ev$Delet function code)
```

Output

```
(a0) = updated past event name
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`Ev$Delet` removes an event from the system event table, freeing the entry for use by another event. Events have an implicit use count (initially set to one), which is incremented with each Ev$Link call and decremented with each Ev$UnLnk call. An event may not be deleted unless its use count is zero.

Important: OS-9 does not automatically unlink events when a F$Exit occurs.

Possible Errors

`E$BNam`	Name is syntactically incorrect or longer than 11 characters.
`E$EvNF`	Event not found in the event table.
`E$EvBusy`	The event has a non-zero link count.

Ev$Wait

Wait for Event to Occur

Input

```
d0.l = event ID number
d1.w = 4 (Ev$Wait function code)
d2.l = minimum activation value (signed)
d3.l = maximum activation value (signed)
```

Output

```
d1.l = actual event value
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`Ev$Wait` waits for an event to occur. The event variable is compared to the range specified in d2 and d3. If the value is not in range, the calling process is suspended in a FIFO event queue. It waits until an Ev$Signl occurs that puts the value in range and adds the wait auto-increment (specified at creation) to the event variable.

If the process receives a signal while in the event queue, it is activated even though the event has not actually occurred. The auto-increment is not added to the event variable, and the event value returned is not within the specified range. The caller's intercept routine is executed, but an event error is not returned.

Possible Errors

`E$EvntID`	ID specified is not a valid active event.

Ev$WaitR

Wait for Relative Event to Occur

Input

```
d0.l = event ID number
d1.w = 5 (Ev$WaitR function code)
d2.l = minimum relative activation value (signed)
d3.l = maximum relative activation value (signed)
```

Output

```
d1.l = actual event value
d2.l = minimum actual activation value
d3.l = maximum actual activation value
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`Ev$WaitR` works exactly like Ev$Wait, except that the range specified in d2 and d3 is relative to the current event value. The event value is added to d2 and d3 respectively, and the actual values are returned to the caller. The Ev$Wait function is then executed directly. If an underflow or overflow occurs on the addition, the values $80000000 (minimum integer), and $7fffffff (maximum integer) are used, respectively.

Possible Errors

`E$EvntID`	ID specified is not a valid active event.

Ev$Read

Read Event Value Without Waiting

Input

```
d0.l = event ID number
d1.w = 6 (Ev$Read function code)
```

Output

```
d1.l = current event value
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`Ev$Read` reads the value of an event without waiting or modifying the event variable. You can use this to determine the availability of the event (or associated resource) without waiting.

Possible Errors

`E$EvntID`	ID specified is not a valid active event.

Ev$Info

Return Event Information

Input

```
d0.l = event index (ID number) to begin search
d1.w = 7 (Ev$Info function code)
(a0) = ptr to buffer for event information
```

Output

```
d0.l = event index found
(a0) = data returned in buffer
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`Ev$Info` returns a copy of the 32-byte event table entry associated with an event. Unlike other F$Event functions, Ev$Info only uses the low word of d0. This index is the system event number, ranging from zero to the maximum number of system events minus one. The event information block for the first active event with an index greater than or equal to this index is returned in the caller's buffer. If none exists, an error is returned. `Ev$Info` is provided for utilities needing to determine the status of all active events.

Possible Errors

`E$EvntID`	The index is above all active events.

Ev$Pulse

Signal an Event Occurrence

Input

```
d0.l = event ID number
d1.w = MS bit set to activate all processes in range
       LS bits = 9 (Ev$Pulse function code)
d2.l = event pulse value
```

Output

None

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`Ev$Pulse` signals an event occurrence, but differs from Ev$Signl. The event variable is set to the value passed in d2, and the signal auto-increment is not applied. Then, the Ev$Signl search routine is executed and the original event value is restored.

Possible Errors

`E$EvntID`	The ID specified is not a valid active event.

Ev$Signl

Signal an Event Occurrence

Input

```
d0.l = event ID number
d1.w = MS bit set to activate all processes in range
       LS bits = 8 (Ev$Signl function code)
```

Output

None

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

Ev$Signl signals that an event has occurred. The current event variable is updated with the signal auto-increment specified when the event was created. Then, the event queue is searched for the first process waiting for that event value. If the MS bit of d1 (the function code) is set, all processes in the event queue that have a value in range are activated. The sequence is the same for each event in the queue until the queue is exhausted:

1. The signal auto-increment is added to the event variable.
2. The first process in range is awakened.
3. The event variable is updated with the wait auto-increment.
4. The search continues with the updated value.

Possible Errors

`E$EvntID` The ID specified is not a valid active event.

Ev$Set

Set Event Variable and Signal an Event Occurrence

Input

```
d0.l = event ID number
d1.w = MS bit set to activate all processes in range
       LS bits = A (Ev$Set function code)
d2.l = new event value
```

Output

```
d1.l = previous event value
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`Ev$Set` is similar to the Ev$Signl call, except that the event variable is initially set to the value passed in d2 rather than updated with the signal auto-increment. After this is done, the Ev$Signl routine is executed directly.

Possible Errors

`E$EvntID`	The ID specified is not a valid active event.

Ev$SetR

Set Relative Event Variable and Signal an Event Occurrence

Input

```
d0.l = event ID number
d1.w = MS bit set to activate all processes in range
       LS bits = B (Ev$SetR function code)
d2.l = (signed) increment for event variable
```

Output

```
d1.l = previous event value
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`Ev$SetR` is similar to Ev$Signl, but instead of using the signal auto-increment value to update the event variable, the value in d2 is used. Arithmetic underflows or overflows are set to $80000000 or $7fffffff, respectively.

Possible Errors

`E$EvntID`	The ID specified is not a valid active event.

F$Exit

Terminate the Calling Process

ASM Call

```
OS9 F$Exit
```

Input

```
d1.w = Status code to be returned to parent process
```

Output

```
Process is terminated
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`F$Exit` is the means by which a process can terminate itself. Its data memory area is de-allocated and its primary module is unlinked. All open paths are automatically closed.

The death of the process can be detected by the parent executing a F$Wait call. This returns (to the parent) the status word passed by the child in its Exit call. The shell assumes that the status word is an OS-9 error code that the terminating process wishes to pass back to its parent process. The status word could also be a user-defined status value.

Processes called directly by the shell should only return an OS-9 error code or zero if no error occurred.

Important: The parent *MUST* do a F$Wait before the process descriptor is returned.

A F$Exit call functions as follows:

1. Close all paths.

2. Return memory to system.

3. Unlink primary module and user trap handlers.

4. Free process descriptor of any dead child processes.

5. If parent is dead, free the process descriptor.

6. If parent has not executed a F$Wait call, leave the process in limbo until parent notices the death.

7. If parent is waiting, move parent to active queue, inform parent of death/status, remove child from sibling list, and free its process descriptor memory.

Caveats

Only the primary module and the user trap handlers are unlinked. Unlink any other modules that are loaded or linked by the process before calling F$Exit.

Although F$Exit closes any open paths, it pays no attention to errors returned by the F$Close request. Because of I/O buffering, this can cause write errors to go unnoticed when paths ARE left open. However, by convention, the standard I/O paths (0,1,2) are usually left open.

See Also

`I$Close`, `F$SRtMem`, `F$UnLink`, `F$FindPD`, `F$RetPD`, `F$Fork`, `F$Wait`, and `F$AProc`.

F$Fork

Create a New Process

ASM Call

```
OS9 F$Fork
```

Input

```
d0.w = desired module type/revision (usually
program/object 0=any)
d1.l = additional memory size
d2.l = parameter size
d3.w = number of I/O paths to copy
d4.w = priority
(a0) = module name pointer
(a1) = parameter pointer
```

Output

```
d0.w = child process ID
(a0) = updated beyond module name
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`F$Fork` creates a new process which becomes a child of the caller. It sets up the new process's memory, MPU registers, and standard I/O paths.

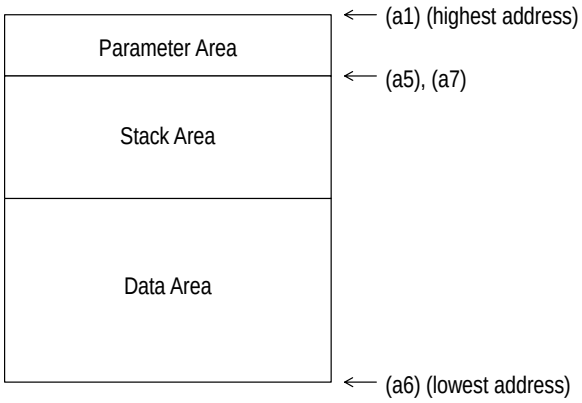
The system parses the name string of the new process's primary module (the program that will initially be executed). Next, the system module directory is searched to see if the program is already in memory. If so, the module is linked and executed. If not, the name string is used as the pathlist of the file which is to be loaded into memory. The first module in this file is linked and executed. To be loaded, the module must be program object code and have the appropriate read and/or execute permissions set for the user.

The primary module's module header is used to determine the process's initial data area size. OS-9 then attempts to allocate RAM equal to the required data storage size plus any additional size specified in d1, plus the size of any parameter passed. The RAM area must be contiguous.

The new process's registers are set up as shown in the diagram on the next page. The execution offset given in the module header is used to set the PC to the module's entry point. If d4.w is set to zero, the new process inherits the same priority as the calling process.

When the shell processes a command line, it passes a copy of the parameter portion (if any) of the command line as a parameter string. The shell appends an end-of-line character to the parameter string to simplify string-oriented processing.

If any of the these operations are unsuccessful, the fork is aborted and an error is returned to the caller. The diagram below shows how F$Fork sets up the data memory area and registers for a newly-created process. For more information, see F$Wait.



Registers passed to child process:

Register:	Description:	Remarks:
sr	0000	(a0) = undefined
pc	module entry point	(a1) = top of memory pointer
d0.w	process ID	(a2) = undefined
d1.l	group/user number	(a3) = primary (forked) module
d2.w	priority	pointer
d3.w	number of I/O paths inherited	(a4) = undefined
d4.l	undefined	(a5) = parameter pointer
d5.l	parameter size	(a6) = static storage (data area)
d6.l	total initial memory allocation	base pointer
d7.l	undefined	(a7) = stack pointer (same as a5)

Important: `(a6)` will actually be biased by $8000, but this can usually be ignored because the linker biases all data references by –$8000. However, it may be significant to note when debugging programs.

Caveats

Both the child and parent process execute concurrently. If the parent executes a F$Wait call immediately after the fork, it waits until the child dies before it resumes execution. A child process descriptor is returned only when the parent does a F$Wait call.

Modules owned by a super-user execute in system state if the system-state bit in the module's attributes is set. This is rarely necessary, quite dangerous, and not recommended for beginners.

See Also

`F$Wait`, `F$Exit`, and `F$Chain`.

Possible Errors

`E$IPrcID`

F$GBlkMp

Get Free Memory Block Map

ASM Call

```
OS9 F$GblkMp
```

Input

```
d0.l = Address to begin reporting segments
d1.l = Size of buffer in bytes
(a0) = Buffer pointer
```

Output

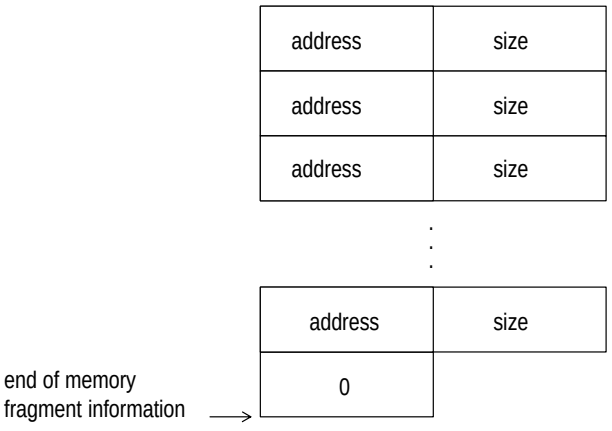
```
d0.l = System's minimum memory allocation size
d1.l = Number of memory fragments in system
d2.l = Total RAM found by system at startup
d3.l = Current total free RAM available
(a0) = Memory fragment information
```

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

F$GBlkMp copies the address and size of the system's free RAM blocks into the user's buffer for inspection. It also returns various information concerning the free RAM as noted by the output registers above. The address and size of the free RAM blocks are returned in the user's buffer in following format (address and size are 4-bytes):



Although F$GblkMp returns the address and size of the system's free memory blocks, these blocks may never be accessed directly. Use F$SRqMem to request free memory blocks.

See Also

`F$SRqMem` and `F$Mem`.

Caveats

`F$GBlkMp` provides a status report concerning free system memory for mfree and similar utilities. The address and size of free RAM changes with system use. Although F$GblkMp returns the address and size of the system's free memory blocks, these blocks may never be accessed directly. Use F$SRqMem to request free memory blocks.

F$GModDr

Get Copy of Module Directory

ASM Call

```
OS9 F$GModDr
```

Input

```
d1.l = Maximum number of bytes to copy
(a0) = Buffer pointer
```

Output

```
d1.l = Actual number of bytes copied
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$GModDr` copies the system's module directory into the user's buffer for inspection. `mdir` uses `F$GModDr` to look at the module directory. Although the module directory contains pointers to each module in the system, the modules should never be accessed directly. Rather, use a F$CpyMem call to copy portions of the system's address space for inspection. On some systems, directly accessing the modules may cause address or bus trap errors.

See Also

`F$Move` and `F$CpyMem`.

Caveats

This system call is provided primarily for use by mdir and similar utilities. The format and contents of the module directory may change on different releases of OS-9. For this reason, it is often preferable to use the output of mdir to determine the names of modules in memory.

F$GPrDBT

Get Copy of Process Descriptor Block Table

ASM Call

```
OS9 F$GPrDBT
```

Input

```
d1.l = maximum number of bytes to copy
(a0) = Buffer pointer
```

Output

```
d1.l = Actual number of bytes copied
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$GPrDBT` copies the process descriptor block table into the caller's buffer for inspection. The procs utility uses F$GPrDBT to quickly determine which processes are active in the system. Although F$GPrDBT returns pointers to the process descriptors of all processes, NEVER access the process descriptors directly. Instead, use the F$GPrDsc system call if you need to inspect particular process descriptors.

The system call, F$AllPd, describes the format of the process descriptor block table.

See Also

`F$GPrDsc` and `F$AllPd`.

F$GPrDsc

Get Copy of the Process Descriptor

ASM Call

```
OS9 F$GPrDsc
```

Input

```
d0.w = Requested process ID
d1.w = Number of bytes to copy
(a0) = Process descriptor buffer pointer
```

Output

None

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$GPrDsc` copies a process descriptor into the caller's buffer for inspection. There is no way to change data in a process descriptor. The procs utility uses F$GPrDsc to gain information about an existing process.

See Also

`F$GPrDBT`

Caveats

The format and contents of a process descriptor may change with different releases of OS-9.

Possible Errors

`E$PrcID`

F$Gregor

Get Gregorian Date

ASM Call

```
OS9 F$Gregor
```

Input

```
d0.l = time (seconds since midnight)
d1.l = Julian date
```

Output

```
d0.l = time (00hhmmss)
d1.l = date (yyyymmdd)
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$Gregor` converts Julian dates to Gregorian dates. Gregorian dates are considered the normal calendar dates.

The Julian date is similar to the Julian date used by astronomers. It is based on the number of days that have elapsed since January 1, 4713 B.C. Each astronomical Julian day changes at noon. OS-9 differs slightly from the astronomical standard by changing Julian dates at midnight. It is relatively easy to adjust for this, when necessary.

Caveats

The normal (Gregorian) calendar was revised to correct errors due to leap year at different dates throughout the world. The algorithm used by OS-9 makes this adjustment on October 15, 1582. Be careful when you are working with old dates, because the same day may be recorded as a different date by different sources.

Important: `F$Gregor` is the inverse function of F$Julian.

See Also

`F$Julian` and `F$Time`.

F$ID

Get Process ID / User ID

ASM Call

```
OS9 F$ID
```

Input

None

Output

```
d0.w = Current process ID
d1.l = Current process group/user number
d2.w = Current process priority
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$ID` returns the caller's process ID number, group and user ID, and current process priority (all word values). The process ID is assigned by OS9 and is unique to the process. The user ID is defined in the system password file, and is used for system and file security. Several processes can have the same user ID.

F$Icpt

Set Up a Signal Intercept Trap

ASM Call

```
OS9 F$Icpt
```

Input

```
(a0) = Address of the intercept routine
(a6) = Address to be passed to the intercept routine
```

Output

```
Signals sent to the process will cause the intercept
routine to be called instead of the process being
killed.
```

Error Output

None

Function

`F$Icpt` tells OS-9 to install a signal intercept routine: (a0) contains the address of the signal handler routine, and (a6) usually contains the address of the program's data area.

After the F$Icpt call has been made, whenever the process receives a signal, its intercept routine executes. A signal aborts a process which has not used the F$Icpt service request and its termination status (register d1.w) is the signal code. Many interactive programs set up an intercept routine to handle keyboard abort and keyboard interrupt signals.

The intercept routine is entered asynchronously because a signal may be sent at any time (similar to an interrupt) and is passed the following:

```
d1.w = Signal code
(a6) = Address of intercept routine data area
```

The intercept routine should be short and fast, such as setting a flag in the process's data area. Avoid complicated system calls (such as I/O). After the intercept routine is complete, it may return to normal process execution by executing the F$RTE system call.

See Also

`F$RTE` and `F$Send`.

Caveats

Each time the intercept routine is called, 70 bytes are used on the user's stack.

F$Julian

Get Julian Date

ASM Call

```
OS9 F$Julian
```

Input

```
d0.l = time (00hhmmss)
d1.l = date (yyyymmdd)
```

Output

```
d0.l = time (seconds since midnight)
d1.l = Julian date
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$Julian` converts Gregorian dates to Julian dates.

Julian dates are very convenient for computing elapsed time. To compute the number of days between two dates, subtract the lower Julian date number from the higher number.

The Julian day number returned is similar to the Julian date used by astronomers. It is based on the number of days that have elapsed since January 1, 4713 B.C. Each astronomical Julian day changes at noon. OS9 differs slightly from the astronomical standard by changing Julian dates at midnight. It is relatively easy to adjust for this, when necessary.

You can also use the Julian day number to determine the day of the week for a given date. Use the following formula:

```
weekday = MOD(Julian_Date + 2, 7)
```

This returns the day of the week as 0 = Sunday, 1 = Monday, etc.

Caveats

The normal (Gregorian) calendar was revised to correct errors due to leap year at different dates throughout the world. The algorithm used by OS-9 makes this adjustment on October 15, 1582. Be careful when working with old dates, because the same day may be recorded as a different date by different sources.

F$Link

Link to Memory Module

ASM Call

```
OS9 F$Link
```

Input

```
d0.w = Desired module type/language byte (0 = any)
(a0) = Module name string pointer
```

Output

```
d0.w = Actual module type/language
d1.w = Module attributes/revision level
(a0) = Updated past the module name
(a1) = Module execution entry point
(a2) = Module pointer
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$Link` causes OS-9 to search the module directory for a module having a name, language, and type as given in the parameters. If found, the address of the module's header is returned in (a2). The absolute address of the module's execution entry point is returned in (a1). As a convenience, you can obtain this and other information from the module header. The module's link count is incremented to keep track of how many processes are using the module. If the module requested is not re-entrant, only one process may link to it at a time.

If the module's access word does not give the process read permission, the link call fails. Link also fails to find modules whose header has been destroyed (altered or corrupted) in memory.

See Also

`F$Load`, `F$UnLink`, and `F$UnLoad`.

Possible Errors

`E$MNF`, `E$BNam`, and `E$ModBsy`.

F$Load

Load Module(s) From a File

ASM Call

```
OS9 F$Load
```

Input

```
d0.b = Access mode
d1.l = Memory “color” type to load (optional)
(a0) = Pathname string pointer
```

Output

```
d0.w = Actual module type/language
d1.w = Attributes/revision level
(a0) = Updated beyond path name
(a1) = Module execution entry pointer (of first module
loaded)
(a2) = Module pointer
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$Load` opens a file specified by the pathlist. It reads one or more memory modules from the file into memory until it reaches an error or end of file. Then, it closes the file. Modules are usually loaded into the highest physical memory available.

An error can indicate an actual I/O error, a module with a bad parity or CRC, or that the system memory is full.

All modules that are loaded are added to the system module directory, and the first module read is linked. The parameters returned are the same as those returned by a link call, and apply only to the first module loaded.

To be loaded, the file must contain a module or modules that have a proper module header and CRC. The access mode may be specified as either Exec_ or Read_, causing the file to load from the current execution or data directory, respectively.

If any of the modules loaded belong to the super-user, the file must also be owned by the super-user. This prevents normal users from executing privileged service requests.

The input register which specifies memory color type (d1.l) is only referenced if the most significant bit of d0.b is set.

Caveats

`F$Load` does not work on SCF devices.

Possible Errors

`E$MemFul` and `E$BMID`.

F$Mem

Resize Data Memory Area

ASM Call

```
OS9 F$Mem
```

Input

```
d0.l = Desired new memory size in bytes
```

Output

```
d0.l = Actual size of new memory area in bytes
(a1) = Pointer to new end of data segment (+1)
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$Mem` contracts or expands the process's data memory area. The new size requested is rounded up to an even memory allocation block (16 bytes in version 2.0). Additional memory is allocated contiguously upward (towards higher addresses), or de-allocated downward from the old highest address. If d0 equals zero, the call is considered an information request and the current upper bound and size is returned.

This request can never return all of a process's memory, or cause deallocation of memory at its current stack pointer.

The request may return an error upon an expansion request even though adequate free memory exists, because the data area must always be contiguous. Memory requests by other processes may fragment memory into smaller, scattered blocks that are not adjacent to the caller's present data area.

Possible Errors

`E$DelSP`, `E$MemFul`, and `E$NoRAM`.

F$PErr

Print Error Message

ASM Call

```
OS9 F$PErr
```

Input

```
d0.w = Error message path number (0=none)
d1.w = Error number
```

Output

None

Error Output

None

Function

`F$PErr` is the system's error reporting facility. It writes an error message to the standard error path. Most OS-9 systems will print ERROR #mmm.nnn. Error numbers 000:000 to 063:255 are reserved for the operating system.

If an error path number is specified, the path is searched for a text description of the error encountered. The error message path contains an ASCII file of error messages. Each line may be up to 80 characters long. If the error number matches the first seven characters in a line (that is, 000:215), the rest of the line is printed along with the error number.

Error messages may be continued on several lines by beginning each continuation line with a space. An example error file might contain lines like this:

```
000:214 (E$FNA) File not accessible.
```

An attempt to open a file failed. The file was found, but is inaccessible to you in the requested mode. Check the file's owner ID and access attributes.

```
000:215 (E$BPNam) Bad pathlist specified.
```

The pathlist specified is syntactically incorrect.

```
000:216 (E$PNNF) File not found.
```

The pathlist does not lead to any known file.

```
000:218 (E$CEF) Tried to create a file that already exists.

000:253 (E$Share) Non–sharable file busy.
```

The most common way to get this error is to try to delete a file that is currently open. Anytime a file already in use is opened for non-sharable access, this error occurs. It also occurs if you try to access a non-sharable device (for example, a printer) that is busy.

F$PrsNam

Parse a Path Name

ASM Call

```
OS9 F$PrsNam
```

Input

```
(a0) = Name of string pointer
```

Output

```
d0.b = Pathlist delimiter
d1.w = Length of pathlist element
(a0) = Pathlist pointer updated past the optional “/”
character
(a1) = Address of the last character of the name +1
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

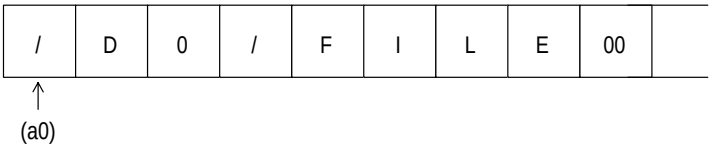
`F$PrsNam` parses a string for a valid pathlist element, returning its size. Note that this does not parse an entire pathname, only one element in it. A valid pathlist element may contain the following characters:

A - Z	Upper case letters	.	Periods
a - z	Lower case letters	_	Underscores
0 - 9	Numbers	$	Dollar signs

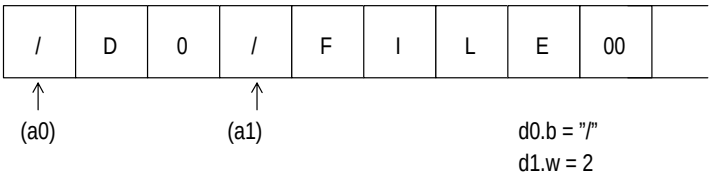
Any other character terminates the name and is returned as the pathlist delimiter.

Important: `F$PrsNam` processes only one name, so several calls may be needed to process a pathlist that has more than one name. `F$PrsNam` terminates a name on recognizing a delimiter character. Pathlists are usually terminated with a null byte.

BEFORE F$PrsNam CALL:



AFTER F$PrsNam CALL:



See Also

`F$CmpNam`

Possible Errors

`E$BNam`

F$RTE

Return From Interrupt Exception

ASM Call

```
OS9 F$RTE
```

Input

None

Output

None

Function

`F$RTE` may be used to exit from a signal processing routine.

F$RTE terminates a process signal intercept routine and continues execution of the main program. However, if there are unprocessed signals pending, the interrupt routine executes again (until the queue is exhausted) before returning to the main program.

Caveats

When a signal is received, 70 bytes are used on the user stack. Consequently, intercept routines should be kept very short and fast if many signals are expected.

See Also

`F$Icpt`

F$SchBit

Search Bit Map For a Free Area

ASM Call

```
OS9 F$SchBit
```

Input

```
d0.w = Beginning bit number to search
d1.w = Number of bits needed
(a0) = Bit map pointer
(a1) = End of bit map (+1) pointer
```

Output

```
d0.w = Beginning bit number found
d1.w = Number of bits found
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$SchBit` searches the specified allocation bit map for a free block (cleared bits) of the required length, starting at the beginning bit number (d0.w). `F$SchBit` returns the offset of the first block found of the specified length.

If no block of the specified size exists, it returns with the carry set, beginning bit number, and size of the largest block found.

See Also

`F$AllBit` and `F$DelBit`.

F$Send

Send a Signal to Another Process

ASM Call

```
OS9 F$Send
```

Input

```
d0.w = Intended receiver's process ID number (0 = all)
d1.w = Signal code to send
```

Output

None

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

F$Send sends a signal to a specific process. The signal code is a word value. A process may send the same signal to multiple processes of the same Group/User ID by passing 0 as the receiver's process ID number. For example, the OS-9 Shell command, kill 0, will unconditionally abort all processes with the same group/user ID (except the Shell itself). This is a handy but dangerous tool to get rid of unwanted background tasks.

If you attempt to send a signal to a process that has an unprocessed, previous signal pending, the signal is placed in a FIFO queue of signals for the individual process. If the process is in the signal intercept routine when it receives a signal, the new signal is processed when F$RTE executes.

If the destination process for the signal is sleeping or waiting, it is activated so that it may process the signal. The signal processing intercept routine is executed, if it exists (see F$Icpt), otherwise the signal aborts the destination process, and the signal code becomes the exit status (see F$Wait).

An exception is the wakeup signal. It activates a sleeping process but does not cause examination of the signal intercept routine and will not abort a process that has not made an F$Icpt call.

Some of the signal codes have meanings defined by convention:

```
S$Kill   = 0 = System abort (unconditional)
S$Wake   = 1 = Wake up process
S$Abort  = 2 = Keyboard abort
S$Intrpt = 3 = Keyboard interrupt
S$HangUp = 4 = Modem Hangup
        5–31 = Reserved for Microware; deadly to I/O
      32–255 = Reserved for Microware
   256–65535 = User defined
```

The S$Kill signal may only be sent to processes with the same group ID as the sender. Super users may kill any process.

Caveat

The I/O system uses the S$Wake signal extensively. It is not reliable if used by user-state programs.

Signal values less than 32 (S$Deadly) usually cause the current I/O operation to terminate with an error status equal to the signal value.

See Also

`F$Wait`, `F$Icpt`, and `F$Sleep`.

Possible Errors

`E$IPrcID` and `E$USigP`.

F$SetCRC

Generate Valid CRC in Module

ASM Call

```
OS9 F$SetCRC
```

Input

```
(a0) = module pointer
```

Output

None

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$SetCRC` updates the header parity and CRC of a module in memory. The module may be an existing module known to the system, or simply an image of a module that will subsequently be written to a file. The module must have correct size and sync bytes; other parts of the module are not checked.

See Also

`F$CRC`

Caveats

The module image must start on an even address or an address error occurs.

OS-9 does not permit any modification to the header of a module known to the system. Modifying the header makes the module inaccessible to other processes.

Possible Errors

`E$BMID`

F$SetSys

Set/Examine OS-9 System Global Variables

ASM Call

```
OS9 F$SetSys
```

Input

```
d0.w = offset of system global variable to set/examine
d1.l = size of variable in least significant word (1, 2 or 4 bytes).
The most significant bit, if set, indicates an examination
      request. Otherwise, the variable is changed to the value in
       register d2.
d2.l = new value (if change request)
```

Output

```
d2.l = original value of system global variable
```

Error Output

```
cc = Carry set
d1.w = Appropriate error code
```

Function

`F$SetSys` changes or examines a system global variable. These variables have a D_ prefix in the system library sys.l. Consult the DEFS files for a description of the system global variables.

See Also

`F$SPrior` and the `DEFS Files` section in the OS-9 Technical I/O Manual

Caveats

Only a super-user can change system variables. Any system variable may be examined, but only a few may be altered. The only useful variables that may be changed are D_MinPty and D_MaxAge. Consult Chapter 2 (section on process scheduling) of the OS-9 Technical Overview for an explanation of what these variables control.

The system global variables are OS-9's data area. It is highly likely that they will change from one release to another. You will probably have to relink programs using this system call to run them on future versions of OS9.

ATTENTION: The super-user must be extremely careful when changing system global variables.

F$Sigmask

Masks/Unmasks Signals During Critical Code

ASM Call

```
OS9 F$SigMask
```

Input

```
d0.l = reserved, must be zero
d1.l = process signal level
          0 = clear
          1 = set/increment
         -1 = decrement
```

Output

None

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`F$SigMask` enables or disables signals from reaching the calling process. If a signal is sent to a process whose mask is disabled, the signal is queued until the process mask becomes enabled. The process's signal intercept routine is executed with signals inherently masked.

Two exceptions to this rule are the S$Kill and S$Wake signals. `S$Kill` terminates the receiving process, regardless of the state of its mask. `S$Wake` ensures that the process is active, but does not queue.

When a process makes a F$Sleep or F$Wait system call, its signal mask is automatically cleared. If a signal is already queued, these calls return immediately (to the intercept routine).

Important: Signals are analogous to hardware interrupts. They should be masked sparingly, and intercept routines should be as short and fast as possible.

F$Sleep

Put Calling Process to Sleep

ASM Call

```
OS9 F$Sleep
```

Input

```
d0.l = Ticks/seconds (length of time to sleep)
```

Output

```
d0.l = Remaining number of ticks if awakened prematurely
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$Sleep` deactivates the calling process until the number of ticks requested have elapsed. `Sleep(0)` sleeps indefinitely. `Sleep(1)` gives up a time slice but does not necessarily sleep for one tick. You cannot use F$Sleep to time more accurately than + or – 1 tick, because it is not known when the F$Sleep request was made during the current tick.

A sleep of one tick is effectively a “give up current time slice” request; the process is immediately inserted into the active process queue and resumes execution when it reaches the front of the queue.

A sleep of two or more (n) ticks causes the process to be inserted into the active process queue after (n – 1) ticks occur and resumes execution when it reaches the front of the queue. The process is activated before the full time interval if a signal (in particular S$Wake) is received. Sleeping indefinitely is a good way to wait for a signal or interrupt without wasting CPU time.

The duration of a tick is system dependent, but is usually .01 seconds. If the high order bit of d0.l is set, the low 31 bits are converted from 256ths of a second into ticks before sleeping to allow program delays to be independent of the system’s clock rate.

See Also

`F$Send` and `F$Wait`.

Caveats

The system clock must be running to perform a timed sleep. The system clock is not required to perform an indefinite sleep or to give up a time-slice.

Possible Errors

`E$NoClk`

F$SPrior

Set Process Priority

ASM Call

```
OS9 F$SPrior
```

Input

```
d0.w = Process ID number
d1.w = Desired process priority: 65535 = highest
                                     0 = lowest
```

Output

None

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$SPrior` changes the process priority to the new value specified. A process can only change another process's priority if it has the same user ID. The one exception to this rule is a super user (group ID zero), which may alter any process's priority.

There are two system global variables that affect task-switching. `D_MinPty` is the minimum priority that a task must have for OS-9 to age or execute it. `D_MaxAge` is the cutoff aging point. `D_MinPty` and `D_MaxAge` are initially set in the Init module.

See Also

`F$SetSys` and the section on process scheduling in Chapter 2 of the OS-9 Technical Overview.

Caveats

A very small change in relative priorities has a large effect. For example, if two processes have priorities 100 and 200, the process with the higher priority runs 100 times before the low priority process runs at all. In actual practice, the difference may not be this extreme because programs spend a lot of time waiting for I/O devices.

Possible Errors

`E$IPrcID`

F$SRqCMem

System Request for Colored Memory

ASM Call

```
OS9 F$SRqCMem
```

Input

```
d0.l = Byte count of requested memory
d1.l = Memory type code (0 = any)
```

Output

```
d0.l = Byte count of memory granted
(a2) = Pointer to memory block allocated
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$SRqCMem` allocates a block of a specific type of memory. If a non-zero type is requested, the search is restricted to memory areas of that type. The area with the highest priority is searched first.

When the type code is zero, the search is based only on priority. This allows you to configure a system so that fast on-board memory is allocated before slow off-board memory. Areas with a priority of zero are excluded from the search.

If more than one memory area has the same priority, the area with the largest total free space is searched first. This allows memory areas to be balanced (that is, contain approximately equal amounts of free space).

Memory types or “color codes” are system dependent and may be arbitrarily assigned by the system administrator. Values below 256 are reserved for Microware use.

The number of bytes requested are rounded up to a system defined blocksize, which is currently 16 bytes. The memory always begins on an even boundary.

If –1 is passed in d0.l, the largest block of free memory of the specified type is allocated to the calling process.

F$SRqMem is equivalent to a F$SRqCMem request with a color of zero.

See Also

`F$SRqMem`, `F$SRtMem`, and `F$Mem`; `Init` module memory definitions and Colored Memory discussion in Chapter 2 of the OS-9 Technical Overview.

Possible Errors

`E$MemFul`, `E$NoRAM`, and `E$Damage`.

F$SrqMem

System Memory Request

ASM Call

```
OS9 F$SRqMem
```

Input

```
d0.l = Byte count of requested memory
```

Output

```
d0.l = Byte count of memory granted
(a2) = Pointer to memory block allocated
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

F$SRqMem allocates a block of memory from the top of available RAM. The number of bytes requested is rounded up to a system defined blocksize (currently 16 bytes). This system call is useful for allocating I/O buffers and any other semi-permanent memory. The memory always begins on an even boundary.

If –1 is passed in d0.l, the largest block of free memory is allocated to the calling process.

The maximum number of blocks any process may have allocated is 32. This includes the primary module's static storage area.

Important: This is a limit on the number of segments allocated, not the amount of memory.

See Also

F$SRtMem and F$Mem.

Caveats

The byte count of memory allocated (as well as the pointer to the block allocated) must be saved if the memory is ever to be returned to the system.

Possible Errors

E$MemFul and E$NoRAM.

F$SRtMem

Return System Memory

ASM Call

```
OS9 F$SRtMem
```

Input

```
d0.l = Byte count of memory being returned
(a2) = Address of memory block being returned
```

Output

None

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$SRtMem` de-allocates memory after it is no longer needed. The number of bytes returned is rounded up to a system defined blocksize before the memory is returned. Rounding occurs identically to that done by F$SRqMem.

In user state, the system keeps track of memory allocated to a process and all blocks not returned are automatically de-allocated by the system when a process terminates. In system state, the process must explicitly return its memory.

See Also

`F$SRqMem` and `F$Mem`.

Possible Errors

`E$BPAddr`

F$SSpd

Suspend Process

ASM Call

```
OS9 F$SSpd
```

Input

```
d0.w = process ID to suspend
```

Output

None

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$SSpd` is currently not implemented.

See Also

`F$SetPri` and `F$SetSys`.

Caveats

You can suspend a process by setting its priority below the system's minimum executable priority level (D_SysMin).

F$STime

Set System Date and Time

ASM Call

```
OS9 F$STime
```

Input

```
d0.l = current time (00hhmmss)
d1.l = current date (yyyymmdd)
```

Output

```
Time/date is set
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$STime` sets the current system date/time and starts the system real-time clock to produce time-slice interrupts. `F$STime` is accomplished by putting the date/time packet in the system direct storage area, and then linking the clock module. The clock initialization routine is called if the link is successful.

It is the function of the clock module to:

- Set up any hardware dependent functions to produce system tick interrupts (including moving new date/time into hardware, if needed).
- Install a service routine to clear the interrupt when a tick occurs.

The OS-9 kernel keeps track of the current date and time in software to make clock modules small and simple. Certain utilities and functions in OS-9 expect the clock to be running with an accurate date and time. For this reason, always run F$STime when the system is started. This is usually done in the system startup file.

See Also

`F$Link` and `F$Time`.

Caveats

The date and time are not checked for validity. On systems with a battery-backed clock, it is usually only necessary to supply the year to the F$STime call. The actual date and time are read from the real-time clock.

F$STrap

Set Error Trap Handler

ASM Call

```
OS9 F$STrap
```

Input

```
(a0) = Stack to use if exception occurs
       (or zero to use the current stack)
(a1) = Pointer to service request initialization table
```

Output

None

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$STrap` enters process local Error Trap routine(s) into the process descriptor dispatch table. If an entry for a particular routine already exists, it is replaced.

The following exception errors may be caught by user programs:

```
Bus error
Address error
Illegal instruction
Zero Divide
CHK instruction
TRAPV instruction
Privilege violation
Line 1010 emulator
Line 1111 emulator
```

User programs can also catch the following exception errors on systems with a floating point coprocessor (68020 or 68030 with 68881/882; or 68040):

```
Branch or set on unordered condition
Inexact result
Divide by zero
Underflow
Operand Error
Overflow
NAN signaled
```

If a user routine is not provided and one of these exceptions occur, the program is aborted. An example initialization table might look like:

```
ExcpTbl   dc.w   T_TRAPV,OvfError-*-4
          dc.w   T_CHK,CHKError-*-4
          dc.w   -1 End of Table
```

When an exception routine is executed, it is passed the following:

```
d7.w = Exception vector offset
(a0) = Program counter when exception occurred
       (same as R$PC(a5))
(a1) = Stack pointer when exception occurred (R$a7(a5))
(a5) = User's register stack image when exception occurred
(a6) = user's primary global data pointer
```

To return to normal program execution after handling the error, the exception must restore all registers (from the register image at (a5)), and jump to the return program counter. For some kinds of exceptions (especially bus and address errors) this may not be appropriate. It is the user program's responsibility to determine whether and where to continue execution.

It is possible to disable an error exception handler. This is done by calling F$STrap with an initialization table that specifies zero as the offset to the routine(s) that are to be removed. For example, the following table removes user routines for the trapv and chk error exceptions:

```
Table     dc.w  T_TRAPV, 0
          dc.w  T_CHK, 0
          dc.w  -1
```

Caveats

Beware of exceptions in exception handling routines. They are usually not re-entrant.

F$SUser

Set User ID Number

ASM Call

```
OS9 F$SUser
```

Input

```
d1.l = Desired group/user ID number
```

Output

None

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$SUser` alters the current user ID to the specified ID. The following restrictions govern the use of F$SUser:

- User number 0.0 may change their ID to anything without restriction.
- A primary module owned by user 0.0 may change its ID to anything without restriction.
- Any primary module may change its user ID to match the module's owner.

All other attempts to change user ID number return an E$Permit error.

F$SysDbg

Call System Debugger

ASM Call

```
OS9 F$SysDbg
```

Input

None

Output

None

Error Output

```
cc = Carry set
d1.w = Appropriate error code
```

Function

`F$SysDbg` invokes the system level debugger, if one exists, to allow system-state routines, such as device drivers, to be debugged. The system level debugger runs in system state and effectively stops timesharing whenever it is active. It should never be used when there are other users on the system. This call can be made only by a user with a group.user ID of 0.0.

Caveats

You must enable the system debugger before installing breakpoints or attempting to trace instructions. If no system debugger is available, the system is reset. The system debugger takes over some of the exception vectors directly, in particular the Trace exception. This makes it impossible to use the user debugger when the system debugger is enabled.

F$Time

Get System Date and Time

ASM Call

```
OS9 F$Time
```

Input

```
d0.w = Format    0 = Gregorian
                 1 = Julian
                 2 = Gregorian with ticks
                 3 = Julian with ticks
```

Output

```
d0.l = Current time
d1.l = Current date
d2.w = day of week (0 = Sunday to 6 = Saturday)
d3.l = tick rate/current tick (if requested)
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$Time` returns the current system date and time. In the (normal) Gregorian format, time is expressed as 00hhmmss, and date as yyyymmdd. The Julian format expresses time as seconds since midnight, and date as the Julian day number. You can use this to determine the elapsed time of an event. If ticks are requested, the clock tick rate in ticks per second is returned in the most significant word of d3. The least significant word contains the current tick.

The following chart illustrates the values returned in the registers:

	Register	Offset	Gregorian Format	Julian Format
d0.l	byte	3	zero	seconds since midnight (long) 0–86399
		2	hour (0–23)	
		1	minute (0–59)	
		0	second (0–59)	
d1.l	byte	2–3	year (integer)	Julian day number (long)
		1	month (1–12)	
		0	day (1–31)	

See Also

`F$STime` and `F$Julian`.

Caveats

`F$Time` returns a date and time of zero (with no error) if no previous call to F$STime is made. A tick rate of zero indicates the clock is not running.

F$TLink

Install User Trap Handler Module

ASM Call

```
OS9 F$TLink
```

Input

```
d0.w = User Trap Number (1–15)
d1.l = Optional memory override
(a0) = Module name pointer
       If (a0)=0 or [(a0)]=0, trap handler is unlinked.
       Other parameters may be required for specific
trap handlers.
```

Output

```
(a0) = Updated past module name
(a1) = Trap library execution entry point
(a2) = Trap module pointer
Other values may be returned by specific trap handlers
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

You can use user traps as a convenient way to link into a standard set of library routines at execution time. This provides the advantage of keeping user programs small, and automatically updating programs that use the library code if it is changed (without having to re-compile or re-link the program itself). Most Microware utilities use one or more trap libraries.

F$TLink attempts to link, or load, the named module, installing a pointer to it in the user's process descriptor for subsequent use in trap calls. If a trap module already exists for the specified trap code, an error is returned. OS9 allocates and initializes static storage for the trap handler, if necessary. You can remove traps by passing a null pointer.

A user program calls a trap routine using the following assembly language directive:

```
tcall N,Function
```

This is the equivalent to:

```
trap #N
dc.w Function
```

“N” can be 1 to 15 (specifying which user trap vector to use). The function code is not used by OS-9, except that it is passed to the trap handler, and the program counter is skipped past it.

F$TLink allows the program to delay installation of the handler until a trap is actually used in the program. If a user program executes a user trap call before the corresponding F$TLink call has been made, the system executes the user’s default trap exception entry point (specified in the module header) if one exists.

See Also

Chapter 5 on User Trap Handlers.

Caveat

System-state processes should not attempt to use trap handlers.

F$Trans

Translate Memory Address

ASM Call

```
OS9 F$Trans
```

Input

```
d0.l = size of block to translate
d1.l = mode: 0 – local CPU address to external bus addr
             1 – external bus address to local CPU addr
(a0) = address of block
```

Output

```
d0.l = size of block translated
(a0) = translated address of block
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

On systems with dual-ported memory, a memory location may appear at different addresses depending upon whether it is accessed via the “local” CPU bus or the system’s external bus. You can use the F$Trans request to translate an address to or from its external bus address.

F$Trans is used when the external bus address must be passed to hardware devices, such as DMA-type controllers. Using the local CPU bus address is faster and reduces the traffic on the external bus. Generally, you should only use the system’s external bus address if it is not possible to use the local CPU bus address.

If the specified source block is non-linear with respect to its destination mapping, F$Trans returns the maximum number of bytes accessible at the translated address. In this case, subsequent calls to F$Trans must be made until the entire block has been successfully translated. This is rare, since OS-9’s memory management routines do not allocate non-linear blocks.

See Also

OS-9 Technical Overview, Chapter 2, sections on Init module memory definitions and Colored Memory.

Possible Errors

`E$UnkSvc`, `E$Param`, and `E$IBA`.

F$UAcct

User Accounting

ASM Call

```
OS9 F$UAcct
```

Input

```
d0.w = Function code (F$Fork, F$Chain, F$Exit)
(a0) = Process descriptor pointer
```

Output

None

Error Output

```
cc = carry bit set
d1.w = error code if error
```

Function

`F$UAcct` is a user-defined system call which may be installed by an OS9P2 module. It is called in system state at the beginning and end of every process, in other words, whenever F$Fork, F$Chain, or F$Exit is executed.

The kernel's fork and chain routines make an F$UAcct request just before a new process is inserted in the active queue. Since the new process is ready to execute, its user number, priority, primary module, parameters, etc. are known to F$UAcct. This provides a variety of opportunities for a F$UAcct routine. For example:

- A system administrator could keep track of every program run and who ran what program.
- F$UAcct could automatically lower the priority of particular programs.
- F$UAcct could keep a log of everything a specific user does.

Important: If F$UAcct returns an error during F$Fork, the new process terminates with the error code in d1.w.

OS-9's process termination routine makes a F$UAcct request just before a process's resources are returned to the system. The process descriptor contains information about how much CPU time was consumed, how

many bytes were read or written, how many system calls were made, etc. Once again, F$UAcct could be used to record or react to this information. The system ignores any F$UAcct error returned at the end of a process.

Important: The values in all registers except d0 and d1 must be preserved.

See Also

`F$SSvc`; OS-9 Technical Overview, Chapter 2 (section on installing system-state routines).

Possible Errors

`E$UnkSvc` and `E$Param`.

F$UnLink

Unlink Module by Address

ASM Call

```
OS9 F$UnLink
```

Input

```
(a2) = Address of the module header
```

Output

None

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$UnLink` tells OS-9 that the module is no longer needed by the calling process. The module's link count is decremented. When the link count equals zero, the module is removed from the module directory and its memory is de-allocated. When several modules are loaded together as a group, modules are only removed when the link count of all modules in the group have zero link counts.

Device driver modules in use and certain system modules cannot be unlinked.

See Also

`F$UnLoad`

Caveats

Repetitive UnLink calls to the same module artificially lower its link count, regardless of the number of current users. If the link count becomes zero while the module is being used, it is removed from the module directory and its memory de-allocated. This causes severe problems for whoever is currently using the module, and may crash the system.

F$UnLoad

Unlink Module by Name

ASM Call

```
OS9 F$UnLoad
```

Input

```
d0.w = Module type/language
(a0) = Module name pointer
```

Output

```
(a0) = Updated past module name
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$UnLoad` locates the module in the module directory, decrements its link count, and removes it from the directory if the count reaches zero. Note that this call differs from F$UnLink in that the pointer to the module name is supplied rather than the address of the module header.

See Also

`F$UnLink`

Caveat

Repetitive UnLoad calls to the same module artificially lower its link count, regardless of how many users are currently using it. If the link count becomes zero while the module is being used, it is removed from the module directory and its memory de-allocated. This causes severe problems for whoever is currently using the module, and may crash the system.

F$Wait

Wait For Child Process to Terminate

ASM Call

```
OS9 F$Wait
```

Input

None

Output

```
d0.w = Terminating child process's ID
d1.w = Child process's exit status code
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$Wait` causes the calling process to deactivate until a child process terminates by executing a F$Exit system call, or otherwise is terminated. The child's ID number and exit status are returned to the parent. If the child process died due to a signal, the exit status word (register d1) is the signal code.

If the caller has several child processes, the caller is activated when the first one dies, so one Wait system call is required to detect termination of each child.

If a child process died before the Wait call, the caller is reactivated immediately. `Wait` returns an error only if the caller has no child processes.

See Also

`F$Exit`, `F$Send`, and `F$Fork`.

Caveats

The process descriptors for child processes are not returned to free memory until their parent process does a F$Wait system call or terminates.

If a signal is received by a process waiting for children to terminate, it is activated. In this case, d0.w contains zero, since no child process has terminated.

Possible Errors

`E$NoChld`

I$Attach

Attach a New Device to the System

ASM Call

```
OS9 I$Attach
```

Input

```
d0.b = Access mode (Read_, Write_, Updat_)
(a0) = Device name pointer
```

Output

```
(a2) = Address of the device table entry
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`I$Attach` causes an I/O device to become known to the system. You use it to attach a new device to the system, or to verify that it is already attached.

The device's name string is used to search the system module directory to see if a device descriptor module with the same name is in memory (this is the name by which the device is known). The descriptor module contains the name of the device's file manager, device driver, and other related information.

If the descriptor is found and the device is not already attached, OS-9 links to its file manager and device driver. It then places their addresses in a new device table entry. Any permanent storage needed by the device driver is allocated, and the driver's initialization routine is called to initialize the hardware. If the device has already been attached, it is not re-initialized.

The access mode parameter may be used to verify that subsequent read and/or write operations are permitted. An Attach system call is not required to perform routine I/O. It does not reserve the device in question; I$Attach simply prepares it for subsequent use by any process.

The kernel attaches all devices at open, and detaches them at close.

Important: `Attach` and `Detach` for devices are similar to Link and Unlink for modules; they are usually used together. However, system performance can improve slightly if all devices are attached at startup. This increments each device's use count and prevents the device from being re-initialized every time it is opened. This also has the advantage of allocating the static storage for devices all at once, which minimizes memory fragmentation. If this is done, the device driver termination routine is never executed.

See Also

`I$Detach`

Possible Errors

`E$DevOvf`, `E$BMode`, `E$DevBsy`, and `E$MemFul`.

I$ChgDir

Change Working Directory

ASM Call

```
OS9 I$ChgDir
```

Input

```
d0.b = Access mode (read/write/exec)
(a0) = Address of the pathlist
```

Output

```
(a0) = Updated past pathname
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`ChgDir` changes a process's working directory to another directory file specified by the pathlist. Depending on the access mode given, either the execution or the data directory (or both) may change. The file specified must be a directory file, and the caller must have access permission for the specified mode.

ACCESS MODES:
1 = Read
2 = Write
3 = Update (read and write)
4 = Execute

If the access mode is read, write, or update, the current data directory changes. If the access mode is execute, the current execution directory changes. Both can change simultaneously.

Important: The shell CHD directive uses UPDATE mode, which means you must have both read and write permission to change directories from the shell. This is a recommended practice.

Possible Errors

`E$BPNam` and `E$BMode`.

I$Close

Close a Path to a File/Device

ASM Call

```
OS9 I$Close
```

Input

```
d0.w = Path number
```

Output

None

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`I$Close` terminates the I/O path specified by the path. The path number is no longer valid for any OS-9 calls unless it becomes active again through an Open, Create, or Dup system call. When pathlists to non-sharable devices are closed, the devices become available to other requesting processes. If this is the last use of the path (that is, it has not been inherited or duplicated by I$Dup), all OS-9 internally managed buffers and descriptors are deallocated.

Important: The OS-9 F$Exit service request automatically closes any open paths. By convention, standard I/O paths are not closed unless it is necessary to change the files/devices they correspond to.

See Also

`I$Detach`

Caveats

`I$Close` does an implied I$Detach call. If this causes the device use count to become zero, the device termination routine is executed.

Possible Errors

`E$BPNum`

I$Create

Create a Path to New File

ASM Call

```
OS9 I$Create
```

Input

```
d0.b = Access mode (S, I, E, W, R)
d1.w = File attributes (access permission)
d2.l = Initial allocation size (optional)
(a0) = Pathname pointer
```

Output

```
d0.w = Path number
(a0) = Updated past the pathlist
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`I$Create` creates a new file. On multi-file devices, the new file name is entered in the directory structure, and Create is synonymous with Open.

The access mode parameter passed in register d0.b must have the write bit set if any data is to be written to the file. The file is given the attributes passed in the register d1.w. The individual bits are defined as follows:

Mode bits (d0.w)	Attribute bits (d1.w)
0 = read	0 = owner read permit
1 = write	1 = owner write permit
2 = execute	2 = owner execute permit
5 = initial file size	3 = public read permit
6 = single user	4 = public write permit
	5 = public execute permit
	6 = non-sharable file

If the execute bit (bit 2) of the access mode byte is set, directory searching begins with the working execution directory instead of the working data directory.

The path number returned by OS-9 identifies the file in subsequent I/O service requests until the file is closed.

WRITE automatically allocates file space for the file. The SETSTAT call (SS_Size) explicitly allocates file space. If the size bit (bit 5) is set, an initial file size estimate may be passed in d2.l.

An error occurs if the pathlist specifies a file name that already exists. You cannot use I$Create to make directory files (see I$MakDir).

Create causes an implicit I$Attach call. If the device has not previously been attached, the device's initialization routine is executed.

See Also

`I$Attach`, `I$Open`, `I$Close`, and `I$MakDir`.

Caveats

The caller is made the owner of the file. To maintain compatibility with OS9/6809 disk formats, there is only space for two bytes of owner ID. The LS byte of the user's group and the LS byte of the user's ID are used as the owner ID. All user's with the same group ID may access the file as the owner.

If an initial file size is specified with I$Create, the exact amount specified may not be allocated. You must execute a SS_Size SetStat after creating the file to ensure that sufficient space was allocated.

Possible Errors

`E$PthFul` and `E$BPNam`.

I$Delete

Delete a File

ASM Call

```
OS9 I$Delete
```

Input

```
d0.b = Access mode (read/write/exec)
(a0) = Pathname pointer
```

Output

```
(a0) = Updated past pathlist
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`I$Delete` deletes the file specified by the pathlist. The caller must have non-sharable write access to the file (the file may not already be open) or an error results. An attempt to delete a non-multifile device results in an error.

The access mode is used to specify the data or execution directory (but not both) in the absence of a full pathlist. If the access mode is read, write, or update, the current data directory is assumed. If the execute bit is set, the current execution directory is assumed. Note that if a full pathlist is specified, that is, a pathlist beginning with a slash (/), the access mode is ignored.

See Also

`I$Detach`, `I$Attach`, `I$Create`, and `I$Open`.

Possible Errors

`E$BPNam`

I$Detach

Remove a Device From the System

ASM Call

```
OS9 I$Detach
```

Input

```
(a2) = Address of the device table entry
```

Output

None

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`I$Detach` removes a device from the system device table, if not in use by any other process. If this is the last use of the device, the device driver's termination routine is called, and any permanent storage assigned to the driver is de-allocated. The device driver and file manager modules associated with the device are unlinked and may be lost if not in use by another process. It is crucial for the termination routine to remove the device from the IRQ system.

You must use the I$Detach service request to un-attach devices that were attached with the I$Attach service request. Both of these are used mainly by the kernel and are of limited use to the typical user. SCF also uses Attach/Detach to set up its second (echo) device.

Most devices are attached at startup and remain attached. Seldom used devices can be attached to the system and used for a while, then detached to free system resources when no longer needed.

See Also

`I$Attach` and `I$Close`.

Caveats

If an invalid address is passed in (a2), the system may crash or undergo severe damage.

I$Dup

Duplicate a Path

ASM Call

```
OS9 I$Dup
```

Input

```
d0.w = Path number of path to duplicate
```

Output

```
d0.w = New number for the same path
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

Given the number of an existing path, I$Dup returns a synonymous path number for the same file or device. `I$Dup` always uses the lowest available path number. For example, if you do I$Close on path #0, then do I$Dup on path #4, path #0 is returned as the new path number. In this way, the standard I/O paths may be manipulated to contain any desired paths.

The shell uses this service request when it redirects I/O. Service requests using either the old or new path numbers operate on the same file or device.

Caveats

This only increments the use count of a path descriptor and returns a synonymous path number. The path descriptor is NOT copied. It is usually not a good idea for more than one process to be doing I/O on the same path concurrently. On RBF files, unpredictable results may occur.

Possible Errors

`E$PthFul` and `E$BPNum`.

I$GetStt

Get File/Device Status

ASM Call

```
OS9 I$GetStt
```

Input

```
d0.w = Path number
d1.w = Function code
Others = dependent on function code
```

Output

```
Dependent on function code
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

This is a wild card call used to handle individual device parameters that are not uniform on all devices, or are highly hardware dependent. The exact operation of this call depends on the device driver and file manager associated with the path.

A typical use is to determine a terminal's parameters (echo on/off, delete character, etc.). It is commonly used in conjunction with the SetStt call, which sets the device operating parameters.

The mnemonics for the status codes are found in the relocatable library sys.l or usr.l. Codes 0-127 are reserved for Microware use. The remaining codes and their parameter passing conventions are user definable (see the OS-9 Technical Overview section on device drivers in Chapter 3). Presently defined function codes are listed below.

Possible Errors

```
E$BPNum
```

SS_DevNum

Return Device Name (ALL)

Input

```
d0.w = Path number
d1.w = #SS_DevNm function code
(a0) = Address of 32 byte area for device name
```

Output

```
Device name in 32 byte storage area, null terminated
```

SS_EOF

Test for End of File (RBF, SCF, PIPE)

Input

```
d0.w = Path number
d1.w = #SS_EOF function code
```

Output

```
d1.l = 0 If not EOF, (SCF never returns EOF)
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code (E$EOF, if end of file)
```

SS_CDFD

Return File Descriptor (CDFM)

Input

```
d0.w = Path number
d1.w = #SS_CDFD function code
d2.w = Number of bytes to copy
(a0) = Pointer to buffer area for file
       descriptor
```

Output

None

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`SS_CDFD` reads the file descriptor describing the path number. The file descriptor may be read for information purposes only, as there are no user changeable parameters.

SS_FD

Read File Descriptor Sector (RBF, PIPE)

Input

```
d0.w = Path number
d1.w = #SS_FD function code
d2.w = Number of bytes to copy(<=logical sector size of
media)
(a0) = Address of buffer area for FD
```

Output

```
File descriptor copied into buffer
```

Function

Use SS_FD to inspect the file descriptor information (for example, FD_OWN and FD_DAT) and the file segment list.

SS_FDInf

Get Specified File Descriptor Sector (RBF)

Input

```
d0.w = Path number
d1.w = #SS_FDInf function code
d2.w = Number of bytes to copy (<=256)
d3.l = FD sector address
(a0) = Address of buffer area for FD
```

Output

```
File descriptor copied into buffer
```

Important: If SS_FDInf is called in user state, the caller must be a super-group user. If it is called in system state, the caller does not have to be a super-group user.

SS_Free

Return Amount of Free Space on Device (NRF, NVRAM file mgr.)

Input

```
d0.l = Path number
d1.w = #SS_Free function code
```

Output

```
d0.l = Size of free space on device, in bytes
```

SS_Opt

Read PD_OPT: The Path Descriptor Option Section. (All)

Input

```
d0.w = Path number
d1.w = #SS_Opt function code
(a0) = Address to put a 128 byte status packet
```

Output

```
Status packet copied to buffer
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`SS_Opt` reads the option section of the path descriptor and copies it into the 128 byte area pointed to by (a0). It is typically used to determine the current settings for echo, auto line feed, etc. For a complete description of the status packet, refer to Chapter 3 of the OS-9 Technical Overview, the section on file manager path descriptors.

SS_Pos

Get Current File Position (RBF, PIPE)

Input

```
d0.w = Path number
d1.w = #SS_Pos function code
```

Output

```
d2.1 = Current file position
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

SS_Ready

Test for Data Ready (RBF, SCF, PIPE)

Input

```
d0.w = Path number
d1.w = #SS_Ready function code
```

Output

```
d1.l = Number of input characters available on SCF or pipe
       devices.
       RBF devices always return carry clear, d1.l=1
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code (E$NotRdy if no data is
       available)
```

SS_Size

Return Current File Size (RBF, PIPE)

Input

```
d0.w = Path number
d1.w = #SS_Size function code
```

Output

```
d2.l = Current file size
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

SS_VarSect

Query Support for Variable Logical Sector Sizes (RBF)

Input

```
d0.w = path number
d1.w – #SS_VarSect function code
```

Output

None

Function

SS_VarSect is an internal call between RBF and a driver. If the driver does not return an error, the logical sector size of the media is specified in PD_SSize. If the driver returns an error, and the error is E$UnkSvc, RBF sets the path's logical sector size to 256 bytes and ignores PD_SSize. If any other error is returned, the path open is aborted and the error is returned to the caller.

I$MakDir

Make a New Directory

ASM Call

```
OS9 I$MakDir
```

Input

```
d0.b = Access mode (see below)
d1.w = Access permissions
d2.l = Initial Allocation Size (Optional)
(a0) = Pathname pointer
```

Output

```
(a0) = Updated past pathname
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`I$MakDir` is the only way to create a new directory file. It creates and initializes a new directory as specified by the pathlist. The new directory file contains no entries, except for an entry for itself (specified by a dot (.)) and its parent directory (specified by double dot (..)). `Makdir` fails on non-multi-file devices. If the execution bit is set, OS-9 begins searching for the file in the working execution directory (unless the pathlist begins with a slash).

The caller is made the owner of the directory. `MakDir` does not return a path number because directory files are not opened by this request (use I$Open to do so). The new directory automatically has its directory bit set in the access permission attributes. The remaining attributes are specified by the bytes passed in register d1.w which have individual bits defined as listed below (if the bit is set, access is permitted):

Mode bits (d0.w)	Attribute bits (d1.w)
0 = read	0 = owner read permit
1 = write	1 = owner write permit
2 = execute	2 = owner execute permit
5 = initial directory size	3 = public read permit
7 = directory	4 = public write permit
	5 = public execute permit
	6 = non-sharable file
	7 = directory

Possible Errors

`E$BPNam` and `E$CEF`.

I$Open

Open a Path to a File or Device

ASM Call

```
OS9 I$Open
```

Input

```
d0.b = Access mode (D S E W R)
(a0) = Pathname pointer
```

Output

```
d0.w = Path number
(a0) = Updated past pathname
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`I$Open` opens a path to an existing file or device as specified by the pathlist. A path number is returned which is used in subsequent service requests to identify the path. If the file does not exist, an error is returned.

The access mode parameter specifies which subsequent read and/or write operations are permitted as follows (if the bit is set, access is permitted):

Mode Bits
0 = read
1 = write
2 = execute
6 = open file for non sharable use
7 = open directory file

Important: A non-directory file may be opened with no bits set. This allows you to examine the attributes, size, etc. with the GetStt system call, but does not permit any actual I/O on the path.

For RBF devices, use read mode instead of update if the file is not going to be modified. This inhibits record locking, and can dramatically improve system performance if more than one user is accessing the file. The access mode must conform to the access permissions associated with the file or device (see I$Create).

If the execution bit mode is set, OS-9 begins searching for the file in the working execution directory (unless the pathlist begins with a slash).

If the single user bit is set, the file is opened for non-sharable access even if the file is sharable.

Files can be opened by several processes (users) simultaneously. Devices have an attribute that specifies whether or not they are sharable on an individual basis.

Open always uses the lowest path number available for the process.

See Also

`I$Attach`, `I$Create` and `I$Close`.

Caveats

Directory files may be opened only if the Directory bit (bit 7) is set in the access mode.

Possible Errors

`E$PthFul`, `E$BPNam`, `E$Bmode`, `E$FNA`, `E$PNNF`, and `E$Share`.

I$Read

Read Data From a File or Device

ASM Call

```
OS9 I$Read
```

Input

```
d0.w = Path number
d1.l = Maximum number of bytes to read
(a0) = Address of input buffer
```

Output

```
d1.l = Number of bytes actually read
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`I$Read` reads a specified number of bytes from the specified path number. The path must previously have been opened in read or update mode. The data is returned exactly as read from the file/device, without additional processing or editing such as backspace, line delete, etc. If there is not enough data in the file to satisfy the read request, fewer bytes are read than requested, but an end of file error is not returned.

After all data in a file has been read, the next I$Read service request returns an end of file error.

See Also

`I$ReadLn`

Caveats

The keyboard X-ON/X-OFF characters may be filtered out of the input data on SCF-type devices unless the corresponding entries in the path descriptor are set to zero. You may wish to modify the device descriptor so that these values in the path descriptor are initialized to zero when the path is opened. SCF devices usually terminate the read when a carriage return is reached.

For RBF devices, if the file is open for update, the record read is locked out. See the Record Locking section in the RBF chapter of the OS-9 Technical I/O Manual.

The number of bytes requested is read unless:

- the end-of-file is reached
- an end-of-record occurs (SCF only)
- an error condition occurs

Possible Errors

`E$BPNum`, `E$Read`, `E$BMode`, and `E$EOF`.

I$ReadLn

Read a Text Line With Editing

ASM Call

```
OS9 I$ReadLn
```

Input

```
d0.w = Path number
d1.l = Maximum number of bytes to read
(a0) = Address of input buffer
```

Output

```
d1.l = Actual number of bytes read
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`ReadLn` is similar to Read except it reads data from the input file or device until an end-of-line character is encountered. `ReadLn` also causes line editing to occur on SCF-type devices. Line editing refers to backspace, line delete, echo, automatic line feed, etc. Some devices (SCF) may limit the number of bytes that may be read with one call.

SCF requires that the last byte entered be an end-of-record character (normally carriage return). If more data is entered than the maximum specified, it is not accepted and a PD_OVF character (normally bell) is echoed. For example, a ReadLn of exactly one byte accepts only a carriage return to return without error and beeps when other keys are pressed.

After all data in a file has been read, the next I$ReadLn service request returns an end of file error.

See Also

`I$Read`

Possible Errors

`E$BPNum`, `E$Read`, and `E$BMode`.

I$Seek

Reposition the Logical File Pointer

ASM Call

```
OS9 I$Seek
```

Input

```
d0.w = Path number
d1.l = New position
```

Output

None

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`I$Seek` repositions the path's file pointer which is the 32-bit address of the next byte in the file to be read or written. `I$Seek` usually does not initiate any physical positioning of the media.

You can perform a Seek to any value even if the file is not large enough. Subsequent writes automatically expand the file to the required size (if possible), but reads return an end-of-file condition.

Important: A Seek to address zero is the same as a rewind operation.

Seeks to non-random access devices are usually ignored and return without error.

Caveats

On RBF devices, seeking to a new disk sector causes the internal sector buffer to be rewritten to disk if it has been modified. Seek does not change the state of record locks. Beware of seeking to a negative position. RBF takes negatives as large positive numbers.

Possible Errors

`E$BPNum`

I$SetStt

Set File/Device Status

ASM Call

```
OS9 I$SetStt
```

Input

```
d0.w = Path number
d1.w = Function code
Others = Function code dependent
```

Output

```
Function code dependent
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

This is a “wild card” system call used to handle individual device parameters that are not uniform on all devices or are highly hardware dependent. The exact operation of this call depends on the device driver and file manager associated with the path.

A typical use is to set a terminal’s parameters for backspace character, delete character, echo on/off, null padding, paging, etc. It is commonly used in conjunction with the GetStt service request which reads the device’s operating parameters.

The mnemonics for the status codes are found in the relocatable library sys.l or usr.l. Codes 0-127 are reserved for Microware use. The remaining codes and their parameter passing conventions are user definable (see the OS-9 Technical Overview section on device drivers in Chapter 3). Presently defined function codes are listed below.

Possible Errors

```
E$BPNum
```

SS_Attr

Set the File Attributes (RBF, PIPE)

Input

```
d0.w = Path number
d1.w = #SS_Attr function code
d2.w = New attributes
```

Output

None

Function

`SSAttr` changes a file's attributes to the new value, if possible. It is not permitted to set the dir bit of a non-directory file, or to clear the dir bit of a non-empty directory.

SS_Close

Notifies Driver That a Path Has Been Closed (SCF, RBF, SBF)

Input

```
d0.w = path number
d1.w = SS_Close function code
```

Output

None

Function

SS_Close is an internal call for drivers.

SS_DCOff

Sends Signal When Data Carrier Detect Line Goes False (SCF)

Input

```
d0.w = path number
d1.w = SS_DCOff function code
d2.w = Signal code to be sent
```

Output

None

Function

When a modem has finished receiving data from a carrier, the Data Carrier Detect line goes false. `SS_DCOff` sends a signal code when this happens. `SS_DCOn` sends a signal when the line goes true.

SS_DCon

Sends Signal When Data Carrier Detect Line Goes True (SCF)

Input

```
d0.w = path number
d1.w = SS_DCOn function code
d2.w = Signal code to be sent
```

Output

None

Function

When a modem receives a carrier, the Data Carrier Detect line goes true. `SS_DCOn` sends a signal code when this happens. `SS_DCOff` sends a signal when the line goes false.

SS_DsRTS

Disables RTS Line (SCF)

Input

```
d0.w = path number
d1.w = SS_DsRTS function code
```

Output

None

Function

`SS_DsRTS` tells the driver to negate the RTS hardware handshake line.

SS_EnRTS

Enables RTS Line (SCF)

Input

```
d0.w = path number
d1.w = SS_EnRTS function code
```

Output

None

Function

`SS_EnRTS` tells the driver to negate the RTS hardware handshake line.

SS_Feed

Erase Tape (SBF)

Input

```
d0.w = path number
d1.w = SS_Feed function code
d2.l = # of blocks to erase
```

Output

None

Function

`SS_Feed` erases a portion of the tape. The amount of tape erased depends on the capabilities of the hardware used. SBF attempts to use the following: If –1 is passed in d2, SBF erases until the end-of-tape is reached. If d2 receives a positive parameter, SBF erases the amount of tape equivalent to that number of blocks. This depends on both the hardware used and the driver.

SS_FD

Write File Description Sector (RBF)

Input

```
d0.w = Path Number
d1.w = #SS_FD function code
(a0) = Address of FD sector image
```

Output

None

Function

`SS_FD` changes FD sector data. The path must be open for write.

Important: You can only change FD_OWN, FD_DAT, and FD_Creat. These are the only fields written back to disk. Only the super user can change the file's owner ID.

SS_FD should normally be used with GetStat (SS_FD) to read the FD before attempting to change FD sector data.

SS_Lock

Lock Out a Record (RBF)

Input

```
d0.w = Path Number
d1.w = #SS_Lock function code
d2.l = Lockout size
```

Output

None

Function

`SS_Lock` locks out a section of the file from the current file pointer position up to the specified number of bytes.

If 0 bytes are requested, all locks are removed (Record Lock, EOF Lock, and File Lock).

If $FFFFFFFF bytes are requested, then the entire file is locked out regardless of where the file pointer is. This is a special type of file lock that remains in effect until released by SS_Lock(0), a read or write of zero bytes, or the file is closed.

There is no way to gain file lock using only read or write system calls.

SS_Open

Notifies Driver That a Path Has Been Opened

Input

```
d0.w = path number
d1.w = SS_Open function code
```

Output

None

Function

`SS_Open` is an internal call for drivers.

SS_Opt

Write Option Selection of Path Descriptor (ALL)

Input

```
d0.w = Path number
d1.w = #SS_Opt function code
(a0) = Address of a 128 byte status packet
```

Output

None

Function

`SS_Opt` writes the option section of the path descriptor from the 128 byte status packet pointed to by (a0). It is typically used to set the device operating parameters (echo, auto line feed, etc.). This call is handled by the file managers, and only copies values that are appropriate to be changed by user programs.

SS_Relea

Release Device (SCF, PIPE)

Input

```
d0.w = path number
d1.w = SS_Relea function code
```

Output

None

Function

`SS_Relea` releases the device from any SS_SSig, SS_DCOn, or SS_DCOff requests made by the calling process on this path.

SS_Reset

Restore Head to Track Zero (RBF, SBF)

Input

```
d0.w = Path number
d1.w = #SS_Reset function code
```

Output

None

Function

For RBF, this directs the disk head to track zero. It is used for formatting and for error recovery. For SBF, this rewinds the tape.

SS_RFM

Skip Tape Marks (SBF)

Input

```
d0.w = path number
d1.w = SS_RFM function code
d2.l = # of tape marks
```

Output

None

Function

`SS_RFM` skips the number of tape marks specified in d2. If d2 is negative, the tape is rewound the specified number of marks.

SS_Size

Set File Size (RBF, PIPE)

Input

```
d0.w = Path number
d1.w = #SS_Size function code
d2.l = Desired file size
```

Output

None

Function

`SS_Size` sets the file's size.

For pipe files, you can use SS_Size to reset the pipe path (d2.1=0), provided the pipe has no active readers or writers. Any other value in d2.1 is ignored.

SS_Skip

Skip Blocks (SBF)

Input

```
d0.w = path number
d1.w = SS_Skip function code
d2.l = # of blocks to skip
```

Output

None

Function

`SS_Skip` skips the number of blocks specified in d2. If the number is negative, the tape is rewound the specified number of blocks.

SS_SSig

Send Signal on Data Ready (SCF, PIPE)

Input

```
d0.w = Path number
d1.w = SS_SSig function code
d2.w = User defined signal code
```

Output

None

Function

`SS_SSig` sets up a signal to send to a process when an interactive device or pipe has data ready. `SS_SSig` must be reset each time the signal is sent. The device or pipe is considered busy and returns an error if any read request arrives before the signal is sent. Write requests to the device are allowed in this state.

SS_Ticks

Wait Specified Number of Ticks for Record Release (RBF)

Input

```
d0.w = path number
d1.w = #SS_Ticks function code
d2.l = Delay interval
```

Output

None

Function

Normally, if a read or write request is issued for a part of a file that is locked out by another user, RBF sleeps indefinitely until the conflict is removed.

You can use SS_Ticks to return an error (E$Lock) to the user program if the conflict still exists after the specified number of ticks have elapsed.

The delay interval is used directly as a parameter to RBF's conflict sleep request. The value zero (RBF's default) causes a sleep forever until the record is released. A value of one means that if the record is not released immediately, an error is returned. If the high order bit is set, the lower 31 bits are converted from 256th of a second into ticks before sleeping. This allows programmed delays to be independent of the system clock rate.

SS_WFM

Write Tape Marks (SBF)

Input

```
d0.w = path number
d1.w = SS_WFM function code
d2.l = # of tape marks
```

Output

None

Function

`SS_WFM` writes the number of tape marks specified in d2.

SS_WTrk

Write (Format) Track (RBF)

Input

```
d0.w = Path number
d1.w = #SS_WTrk function code
(a0) = Address of track buffer
       For hard disks and “autosize” media, this table
       contains 1 logical sector of data (pattern $E5).
       For floppy disks, this table contains the track’s
       physical data.
(a1) = Address of interleave table
       This table contains byte entries of LSN’s ordered to
       match the requested interleave offset. NOTE: This is
       a “logical” table and does not reflect the PD_SOffs
       base sector number.
d2   = Track number
d3.w = Side/density
       The low order byte has 3 bits which can be set:
           Bit 0 = SIDE (0=side zero;1=side one)
           Bit 1 = DENSITY (0=single;1=double)
           Bit 2 = TRACK DENSITY (0=single;1=double)
       The high order byte contains the side number.
d4   = Interleave value
```

Output

None

Function

`SS_Wtrk` causes a format track operation (used with most floppy disks) to occur. For hard or floppy disks with a “format entire disk” command, this formats the entire media only when side 0 of the first accessable track is specified.

I$Write

Write Data to a File or Device

ASM Call

```
OS9 I$Write
```

Input

```
d0.w = Path number
d1.l = Number of bytes to write
(a0) = Address of buffer
```

Output

```
d1.l = Number of bytes actually written
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`I$Write` outputs bytes to a file or device associated with the path number specified. The path must have been opened or created in the write or update access modes.

Data is written to the file or device without processing or editing. If data is written past the present end-of-file, the file is automatically expanded.

See Also

`I$Open`, `I$Create`, and `I$WritLn`.

Caveats

On RBF devices, any record that was locked is released.

Possible Errors

`E$BPNum`, `E$BMode`, and `E$Write`.

I$WritLn

Write a Line of Text With Editing

ASM Call

```
OS9 I$WritLn
```

Input

```
d0.w = Path number
d1.l = Maximum number of bytes to write
(a0) = Address of buffer
```

Output

```
d1.l = Actual number of bytes written
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`I$WriteLn` is similar to Write except it writes data until a carriage return character or (d1) bytes are encountered. Line editing is also activated for character-oriented devices such as terminals, printers, etc. The line editing refers to auto line feed, null padding at end-of-line, etc.

The number of bytes actually written (returned in d1.l) does not reflect any additional bytes that may have been added by file managers or device drivers for device control. For example, if SCF appends a line feed and nulls after carriage return characters, these extra bytes are not counted.

See Also

`I$Open`, `I$Create`, and `I$Write`; OS-9 Technical I/O Manual chapter on SCF Drivers (line editing).

Caveats

On RBF devices, any record that was locked is released.

Possible Errors

`E$BPNum`, `E$BMode`, and `E$Write`.

F$Alarm

Set Alarm Clock

ASM Call

```
OS9 F$Alarm
```

Input

```
d0.l = Alarm ID (or zero)
d1.w = Function code
d2.l = Reserved, must be zero
d3.l = Time interval (or time)
d4.l = Date (when using absolute time)
(a0) = Register image
```

Output

```
d0.l = Alarm ID
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

When called from system state, F$Alarm causes the execution of a system-state subroutine at a specified time. It is provided for such functions as turning off a disk drive motor if the disk is not accessed for a period of time.

The register image pointed to by register (a0) contains an image of the registers to be passed to the alarm subroutine. The subroutine entry point must be placed in R$pc(a0). The register image is copied by the F$Alarm request into another buffer area and may re-used immediately for other purposes.

The alarm ID returned may be used to delete an alarm request.

The time interval is the number of system clock ticks (or 256ths of a second) to wait before the alarm subroutine is executed. If the high order bit is set, the low 31 bits are interpreted as 256ths of a second.

Important: All times are rounded up to the nearest clock tick.

The system automatically deletes a process's pending alarms when the process dies.

The alarm function code is used to select one of the related alarm functions. Not all input parameters are always needed; each function is described in the following pages.

The following function codes are supported:

Function code:	Description:
A$Delete	Remove a pending alarm request
A$Set	Execute a subroutine after a specified time interval
A$Cycle	Execute a subroutine at specified time intervals
A$AtDate	Execute a subroutine at a Gregorian date/time
A$AtJul	Execute a subroutine at Julian date/time

System-state alarm subroutines must conform to the following conventions:

Input:

```
d0–d7 = caller's registers (R$d0–R$d7(a5))
(a0)–(a3) = caller's registers (R$a0–R$a3(a5))
(a4)  = system process descriptor pointer*
(a5)  = ptr to register image
(a6)  = system global storage pointer
```

Output:

```
cc = carry set
d1.w = error code if error
```

Important: * The user number in the system process descriptor will have been temporarily changed to the user number of original F$Alarm request. The registers d0-d7 and (a0)-(a3) do not have to be preserved.

Caveats

System-state alarms are executed by the system process at priority 65535. They may never perform any function that can result in any kind of queuing, such as F$Sleep, F$Wait, F$Load, F$Event (Ev$Wait), F$IOQu, or F$Fork. When such functions are required, the caller must provide a separate process to perform the function, rather than an alarm.

ATTENTION: If an alarm execution routine suffers any kind of bus trap, address trap, or other hardware-related error, the system will crash.

See Also

`F$Alarm` User-State System Call

Possible Errors

`E$UnkSvc`, `E$Param`, `E$MemFul`, `E$NoRAM`, and `E$BPAddr`.

A$Delete

Remove a Pending Alarm Request

Input

```
d0.l = Alarm ID (or zero)
d1.w = A$Delete function code
```

Output

None

Function

`A$Delete` removes a cyclic alarm or any alarm that has not expired. If zero is passed as the alarm ID, all pending alarm requests for the current process are removed.

A$Set

Execute a System-State Subroutine After a Specified Time Interval

Input

```
d0.l = Reserved, must be zero
d1.w = A$Set function code
d2.w = Reserved, must be zero
d3.l = Time Interval
(a0) = Register image
```

Output

```
d0.l = Alarm ID
```

Error Output

```
cc = carry bit set to one
1.w = Error code
```

Function

`A$Set` executes a system-state subroutine after the specified time interval has elapsed. The time interval may be specified in system clock ticks, or 256ths of a second. The minimum time interval allowed is two system clock ticks.

A$Cycle

Execute a System-State Subroutine Every

Input

```
d0.l = reserved, must be zero
d1.w = A$Cycle function code
d2.l = signal code
d3.l = time interval
```

Output

```
d0.l = alarm ID
```

Error Output

```
cc = carry bit set
d1.w = appropriate error code
```

Function

The cycle function is similar to the set function, except that the alarm is reset after it is sent. This causes periodic execution of a system-state subroutine.

Caveat

Keep cyclic system-state alarms as fast as possible and schedule them with as long a cycle as possible to avoid consuming a large portion of available CPU time.

A$AtDate

Execute a System-State Subroutine at Gregorian Date/Time

Input

```
d0.l = Reserved, must be zero
d1.w = A$AtDate function code
d2.l = Reserved, must be zero
d3.l = Time (00hhmmss)
d4.l = Date (YYYYMMDD)
(a0) = Register image
```

Output

```
d0.l = alarm ID
```

Error Output

```
cc = carry bit set
d1.w = appropriate error code
```

Function

`A$AtDate` executes a system-state subroutine at a specific date and time.

Important: `A$AtDate` only allows you to specify time to the nearest second. However, it does adjust if the system's date and time have changed (via F$STime). The alarm subroutine executes anytime the system date/time becomes greater than or equal to the alarm time.

A$AtJul

Execute a System-State Subroutine at Julian Date/Time

Input

```
d0.l = Reserved, must be zero
d1.w = A$AtDate or A$AtJul function code
d2.l = Reserved, must be zero
d3.l = Time (seconds after midnight)
d4.l = Date (Julian day number)
(a0) = Register image
```

Output

```
d0.l = alarm ID
```

Error Output

```
cc = carry bit set
d1.w = appropriate error code
```

Function

`A$AtJul` executes a system-state subroutine at a specific Julian date and time.

Important: `A$AtJul` function only allows time to be specified to the nearest second. However, it does adjust if the system's date and time have changed (via F$STime). The alarm subroutine is executed anytime the system date/time becomes greater than or equal to the alarm time.

F$AllPD

Allocate Process/Path Descriptor

ASM Call

```
OS9 F$AllPD
```

Input

```
(a0) = process/path table pointer
```

Output

```
d0.w = process/path number
(a1) = pointer to process/path descriptor
```

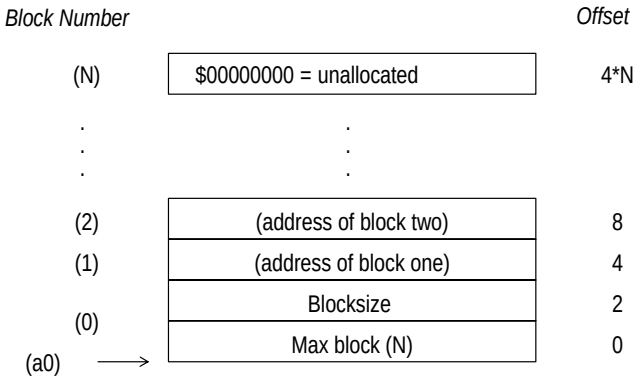
Error Output

```
cc = Carry bit set
d1.w = error code if error
```

Function

`F$AllPD` allocates fixed-length blocks of system memory. It allocates and initializes (to zeros) a block of storage and returns its address.

It can be used with F$FindPD and F$RetPD to perform simple memory management. The system uses these routines to keep track of memory blocks used for process and path descriptors. They can be used generally for similar purposes by creating a map table for the data allocations. The table must be initialized as follows:



See Also

`F$FindPD` and `F$RetPD`.

Important: This is a privileged System-State service request.

F$AllPrc

Allocate Process Descriptor

ASM Call

```
OS9 F$AllPrc
```

Input

None

Output

```
(a2) = Process Descriptor pointer
```

Error Output

```
cc = Carry bit set.
d1.w = Appropriate error code.
```

Function

`F$AllPrc` allocates and initializes a process descriptor. The address of the descriptor is kept in the process descriptor table. Initialization consists of clearing the descriptor, setting up the state as system-state, and marking as unallocated as much of the MMU image as the system allows.

On systems without memory management/protection, this is a direct call to F$AllPD.

See Also

`F$AllPD`

Possible Errors

`E$PrcFul`

Important: This is a privileged System-State service request.

F$AProc

Enter Process in Active Process Queue

ASM Call

```
OS9 F$AProc
```

Input

```
(a0) = Address of process descriptor
```

Output

None

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$AProc` inserts a process into the active process queue so that it may be scheduled for execution. All processes already in the active process queue are aged. The age of the specified process is set to its priority. The process is then inserted according to its relative age. If the new process has a higher priority than the currently active process, the active process gives up the remainder of its time-slice and the new process runs immediately.

Caveats

OS-9 does not pre-empt a process that is in system state (that is, in the middle of a system call). However, OS-9 does set a bit in the process descriptor that cause it to give up its time slice when it re-enters user state.

See Also

`F$NProc`; Chapter 2 of the OS-9 Technical Overview, the section on Process Scheduling

Important: This is a privileged System-State service request.

F$DelPrc

De-Allocate Process Descriptor Service Request

ASM Call

```
OS9 F$DelPrc
```

Input

```
d0.w = process ID to de–allocate
```

Output

None

Error Output

```
cc = carry set
d1.w = appropriate error code
```

Function

`F$DelPrc` de-allocates a process descriptor previously allocated by F$AllPD. It is the caller's responsibility to ensure that any system resources used by the process are returned prior to calling F$DelPrc.

Currently, the F$DelPrc request is simply a convenient interface to the F$RetPD service request. It is preferred to F$RetPD to ensure compatibility with future releases of the operating system that may need to perform process specific de-allocations.

See Also

`F$AllPrc`, `F$AllPD`, `F$FindPD`, and `F$RetPD`.

Possible Errors

`E$BNam` and `E$KwnMod`.

Important: This is a privileged System-State service request.

F$FindPD

Find Process/Path Descriptor

ASM Call

```
OS9 F$FindPD
```

Input

```
d0.w = process/path number
(a0) = process/path table pointer
```

Output

```
(a1) = pointer to process/path descriptor
```

Error Output

```
cc = Carry bit set
d1.w = error code if error
```

Function

`F$FindPD` converts a process or path number to the absolute address of its descriptor data structure. You can use it for simple memory management of fixed length blocks. See F$AllPD for a description of the data structure used.

See Also

`F$AllPd` and `F$RetPd`.

Important: This is a privileged System-State service request.

F$IOQu

Enter I/O Queue

ASM Call

```
OS9 F$IOQu
```

Input

```
d0.w = Process Number
```

Output

None

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$IOQu` links the calling process into the I/O queue of the specified process and performs an untimed sleep. It is assumed that routines associated with the specified process send a wakeup signal to the calling process. `IOQu` is used primarily and extensively by the I/O system.

For example, if a process needs to do I/O on a particular device that is busy servicing another request, the calling process performs an F$IOQu call to the process in control of the device. When the first process returns from the file manager, the kernel automatically wakes up the IOQu-ed process.

See Also

`F$FindPd`, `F$Send`, and `F$Sleep`.

Important: This is a privileged System-State service request.

F$IRQ

Add or Remove Device From IRQ Table

ASM Call

```
OS9 F$IRQ
```

Input

```
d0.b = vector number
       25–31 for autovectors
       57–63 for 68070 on–chip autovectors
       64–255 for vectored IRQs
d1.b = priority (0 = polled first, 255 = last)
(a0) = IRQ service routine entry point (0 = delete)
(a2) = device static storage
(a3) = port address
```

Output

None

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$IRQ` installs an IRQ service routine into the system polling table. If (a0) equals zero, the call deletes the IRQ service routine, and only (d0/a0/a2) are used.

The port is sorted by priority onto a list of devices for the specified vector. If the priority is zero, only this device is allowed to use the vector. Otherwise, any vector may support multiple devices. OS-9 does not poll the I/O port prior to calling the interrupt service routine and makes no use of (a3). Device drivers are required to determine if their device caused the interrupt. Service routines conform to the following register conventions:

Input:

```
(a2) = global static pointer
(a3) = port address
(a6) = system global data pointer (D_’s)
(a7) = system stack (in active proc’s descriptor)
```

Output:

None

Error Output:

`Carry bit set if the device did not cause the interrupt.`

ATTENTION: Interrupt service routines may destroy the following registers: d0, d1, a0, a2, a3, and/or a6. You must preserve all other registers used.

See Also

The OS-9 Technical I/O Manual contains more information on RBF and SCF device drivers.

Caveat

You may not put zero priority multiple auto-vectored devices on the polling list.

Possible Errors

`E$POLL` is returned if the polling table is full.

Important: This is a privileged System-State service request.

F$Move

Move Data (Low Bound First)

ASM Call

```
OS9 F$Move
```

Input

```
d2.1 = Byte count to copy
(a0) = Source pointer
(a2) = Destination pointer
```

Output

None

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

F$Move is a fast “block-move” subroutine capable of copying data bytes from one address space to another (usually from system to user or vice versa).

The data movement subroutine is optimized to make use of long moves whenever possible. If the source and destination buffers overlap, an appropriate move (left to right or right to left) is used to avoid loss of data due to incorrect propagation.

Important: This is a privileged System-State service request.

F$NProc

Start Next Process

ASM Call

```
OS9 F$NProc
```

Input

None

Output

```
Control does not return to caller.
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$NProc` takes the next process out of the Active Process Queue and initiates its execution. If there is no process in the queue, OS-9 waits for an interrupt, and then checks the active process queue again.

Caveats

The process calling NProc should already be in one of the system's process queues. If it is not, the calling process becomes unknown to the system even though the process descriptor still exists and is printed out by a procs command.

See Also

`F$APROC`

Important: This is a privileged System-State service request.

F$Panic

System Catastrophic Occurrence

ASM Call

```
OS9 F$Panic
```

Input

```
d0.l = panic code
```

Output

None. F$Panic generally does not return.

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

The OS-9 kernel makes a F$Panic request when it detects a disastrous, but not necessarily fatal, system condition. Ordinarily, F$Panic is undefined and the system dies.

The system administrator may install a service routine for F$Panic as part of an OS9P2 startup module. The function of such a routine might be to fork a warmstart Sysgo process or to cause the system to re-boot.

Two panic codes are defined:

K$Idle	The system has no processes to execute.
K$PFail	Power failure has been detected.

F$Panic is called only when the kernel believes there are no processes remaining to be executed. Although it is likely the system is dead at this point, it may not be. Interrupt service routines or system-state alarms could cause the system to become active.

Important: The OS-9 kernel does not detect power failure. However, some machines are equipped with hardware capable of detecting power failure. For these machines, an OS9P2 routine could be installed to call F$Panic when power failure occurs.

See Also

F$SSvc; Chapter 2 of the OS-9 Technical Overview, the section on installing system-state routines.

F$RetPD

Return Process/Path Descriptor

ASM Call

```
OS9 F$RetPD
```

Input

```
d0.w = process/path number
(a0) = process/path table pointer
```

Output

None

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$RetPD` de-allocates a process or path descriptor. It can be used in conjunction with F$AllPD and F$FindPD to perform simple memory management of other fixed length objects.

See Also

`F$AllPD` and `F$FindPD`.

Important: This is a privileged System-State service request.

F$SSvc

Service Request Table Initialization

ASM Call

```
OS9 F$SSvc
```

Input

```
(a1) = pointer to service request initialization table
(a3) = user defined
```

Output

None

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

F$SSvc adds or replaces function requests in OS-9's user and privileged system service request tables.

(a3) is intended to point to global static storage. This allows a global data pointer to be associated with each installed system call. Whenever the system call is invoked, the data pointer is automatically passed. Whatever (a3) points to is passed to the system call; (a3) may point to anything.

An example initialization table might look like this:

```
SvcTbl
   dc.w F$Service          OS-9 service request code
   dc.w Routine-*-2        offset of routine to process request
            :
   dc.w F$Service+SysTrap  redefine system level request
   dc.w SysRoutn-*-4       offset of routine to handle system request
            :
   dc.w -1 end of table
```

Valid service request codes range from (0-255).

If the sign bit of the function code word is set, only the system table is updated. Otherwise, both the system and user tables are updated.

You can only call privileged system service requests from routines executing in System (supervisor) state. The example above shows how a service call that must behave differently in system state than it does in user state is installed.

System service routines are executed in supervisor state, and are not subject to time-sliced task-switching. They are written to conform to register conventions shown in the following table:

Input:

```
d0–d4 = user’s values
(a0)–(a2) = user’s values
(a4) = current process descriptor pointer
(a5) = user’s registers image pointer
(a6) = system global data pointer
```

Output:

```
cc = carry set
d1.w = error code if error
```

The service request routine should process its request and return from subroutine with a RTS instruction. Any of the registers d0-d7 and (a0)-(a6) may be destroyed by the routine, although for convenience, (a4)-(a6) are generally left intact.

The user’s register stack frame pointed to by (a5) is defined in the library sys.l and follows the natural hardware stacking order. If the carry bit is returned set, the service dispatcher sets R$cc and R$d1.w in the user’s register stack. Any other values to be returned to the user must be changed in their stack by the service routine.

Important: This is a privileged System-State service request.

F$VModul

Validate Module

ASM Call

```
OS9 F$VModul
```

Input

```
d0.l = beginning of module group (ID)
d1.l = module size
(a0) = module pointer
```

Output

```
(a2) = Directory entry pointer
```

Error Output

```
cc = Carry bit set
d1.w = Appropriate error code
```

Function

`F$VModul` checks the module header parity and CRC bytes of an OS-9 module.

If the header values are valid, the module is entered into the module directory, and a pointer to the directory entry is returned.

The module directory is first searched for another module with the same name. If a module with the same name and type exists, the one with the highest revision level is retained in the module directory. Ties are broken in favor of the established module.

See Also

`F$CRC` and `F$Load`.

Possible Errors

`E$KwnMod`, `E$DirFul`, `E$BMID`, `E$BMCRC`, and `E$BMHP`.

Important: This is a privileged System-State service request.

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