OS-9 INSIGHTS

AN ADVANCED PROGRAMMER'S GUIDE TO OS-9

THIRD EDITION

PETER DIBBLE

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An Advanced Programmers Guide
to OS-9

3.0 Edition

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By

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Foreword

The basis of this book is the latter part of *The Complete Rainbow Guide to OS-9* which Dale Puckett and I wrote for Falsoft several years ago. With the encouragement of Ken Kaplan, and the willing assistance of a large fraction of the Microware technical staff, I brought this book near to the moving target of OS-9/68000.

First thanks go to Don Williams. He gave me my start as a writer for *68' Micro Journal*. Dale Puckett asked me to coauthor *The Complete Rainbow Guide to OS-9* and Lonnie Falk published the resulting book. It is with Lonnie's generous permission that I have used several sections of the Complete Guide that carry over to OS-9/68000.

At Microware, Ken Kaplan supplied encouragement (sometimes gentle prodding) and friendship. Warren Brown, Larry Crane, and Ken Kaplan read drafts and made extensive comments. The Microware technical writing group read the second and third editions carefully and made useful comments. Warren also spent hours worrying over device drivers with me. Robert Doggett and Larry Crane helped with file managers and general OS-9 internals.

Several people scattered around the world offered helpful comments about the first edition of this book. I appreciate this input very much and implemented as many as possible of the improvements they suggested.

My family and friends showed remarkable tolerance while I struggled with this. Melba, my wife, deserves special recognition for soloing with the children and animals while I hid in my "lair."

OS-9 is both the subject and the origin of this book. I wrote the first and second editions on my GMX Micro-20 and the 3.0 edition on a Motorola MVME167 using MicroEmacs (written largely by Daniel M. Lawrence) with some early editing by DynaStar. The typesetting was by Leslie Lamport's LaTeX macro package and the Web2C implementation (by Tomas Rokicki) of Donald Knuth's typesetting program, TeX. The draft output was on a Lexmark 4039 using Tomas Rokicki's ***dvips*** dvi-to-PostScript filter also running under OS-9. Final output was from a PostScript typesetter.

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Introduction

This is the third edition of *OS-9 Insights.* Coincidentally it is also the edition that reflects edition 3.0 of the OS-9 kernel. It is not a massive update on the scale of the second edition, but there is some polishing, several new chapters, and changes throughout. A few statements in the second edition became dangerous lies for OS-9 3.0. They were removed. I hadn't planned to do a new edition this soon. If all had gone according to plan this would be a new volume, not a new edition. Version 3.0 of the kernel changed my plans. The discussion of the signal state stack in the second edition is entirely wrong now, and the presentation of semaphores is a bit silly in the presence of 3.0's fully-supported semaphores.

This edition continues a trend I started in the second edition. The second edition raised the technical level of the book to something closer to the level the people I've met since I've been working at Microware and I've sustained that level. This edition of *Insights* still does not yet have *sufficient* information, but it is getting better.

I am pleased with the reaction to the PCFM file manager presented in the first edition. Since the publication of *Insights,* several new file managers for OS-9 have been produced outside Microware. I like to think PCFM helped encourage file manager construction. This is good and proper exploitation of OS-9. I hope the device driver in C that I added to the second edition will make device driver construction almost as casual as ordinary programming.

This book was written for programmers who would like to use the advanced features of OS-9. It explains and illustrates features of OS-9 ranging from memory management through file managers. The illustrations are examples, either programs or scripts of interactions with OS-9. They are intended to expose the details of the techniques under discussion and suggest interesting applications.

If you have never programmed for OS-9—particularly if you are experienced with another advanced operating system—you can survey the territory by skimming the entire book. Scanning the table of contents will give a faster overview.

Many programmers can use OS-9 very effectively without using *The OS-9 Technical Manual*. Those people will find part of this book useful. I suggest chapter 3, Managing Your Memory; chapter 15, OS-9 I/O; and chapter 20, Managing Disk Space.

Programmers who want to use the full power of OS-9 but don't want to adjust or extend the operating system should read everything up to chapter 27. The chapters on writing file managers and device drivers serve as useful reference material on the details of I/O operations, but they are long and somewhat difficult…probably not worth studying unless you actually intend to write a driver or file manager.

The last few chapters concern operating system code. It is probably easier to add features to OS-9 than you expected (though not actually easy). Chapter 29 is a densely commented SCF device driver, and chapter 30 is a simple SCSI driver written mainly in C. A very simple RBF-like file manager is presented in chapter 27, and a much expanded version of the same file manager (capable of reading and writing PC-DOS disks) is presented in appendix C. The RBF device driver that was presented in the first edition has been moved to appendix D; it is out-of-date and comparatively hard to understand, but it was a production device driver. The C device driver that has taken its place in the main body of the book is easier to understand and probably a better starting point for a new driver, but it has not been tested to the level of production code. The details in ***Rb765*** are messy, but good reference material.

I find myself in a somewhat delicate position. When I wrote the first edition of this book I was an OS-9 fanatic on very good terms with Microware. When I wrote the second edition I was the Research Scientist at Microware, but version 2.4 of OS-9 was written before I started work. I had a lot to do with version 3.0. It is hard to take the same view I used before. Fortunately, my role in Microware's OS group is critic, tester, and general pest. I've tried to keep my feelings about the hard work that went into 3.0 balanced with my annoyance at every compromise that had to be made.

$\TeX$ makes it easy to let typography get out of control. It is easy to typeset text so it is almost impossible to read. Manuals of style suggest rather strongly that book designers restrain themselves. Text that keeps a consistent typestyle is easier to read than text that changes frequently. Typestyles are, however, a convenient way to mark special text. Table 1.1 shows the way fonts are used in this book.

The programs in this book are set in Roman type, slightly smaller than the surrounding text. I have departed from my typographical standard by setting comments for C programs in italic type. This practice has become a standard in the computer science community, and it makes the comments clearly visible.

The two-character C code -> has been replaced with → in all programs. Before I made the change, the leading hyphen was sometimes hard to see. The revised notation makes the operator easier to see, and I think the meaning of → is clear.

The cover of the first edition of *Insights* mentioned a book about CD-I. That book has never appeared, and probably never will. I wrote the book and tried for about six months to keep it current with the evolution of CD-RTOS. Then I gave up. Eric and Walden Miller have written a book on CD-I that is available from Microware. Since Eric is one of the world's leading experts on CD-RTOS, this is an authoritative text.

I still hope to write additional *Insights* volumes. I'd like to investigate some of the deeper possibilities for manipulating the OS-9 kernel, and discuss a number of "dirty tricks." I'd also like to write about real-time programming. I think these books are necessary, but I'm not sure I can write them. My expectations are high and the topics for discussion are controversial (the dirty tricks leave huge opportunities for mysterious and catastrophic bugs), but if everything goes perfectly, I should have another book of about OS-9 ready sometime in 1995.

Table 1.1: Typographic Conventions

Font	Used For
`Typewriter`	Output from a computer
`Script`	OS-9 system calls and CPU op codes
SMALL CAPS	CPU registers
Bold Italics	Program names
Italics	General emphasis
Roman	Everything else

Chapter 2

Modules

In this chapter we investigate OS-9 modules in considerable depth.

One of the first steps in the OS-9 boot procedure is a pass through memory checking for Read Only Memory (ROM), Random Access Memory (RAM) and, in some systems, defective memory. Good RAM is distinguished by its ability to store data. OS-9 tests memory by writing at least two different values into the memory and reading the memory after each write to make certain that the value can be recovered intact. ROM always contains the same data regardless of what is written into it. Unused addresses respond with a bus error when the bootstrap code attempts to read or write them.

The possible addressing ranges for a 68000-family processor extend from 16 megabytes to four gigabytes. A processor's range of addresses probably includes I/O devices that should not be touched during the memory search, and perhaps even multiple addresses that refer to the same memory. This makes a comprehensive search of all addresses for RAM and ROM slow and complicated. The bootstrap code avoids these problems by driving its memory initialization from a list of address ranges that are worth inspecting.

One problem that OS-9's designers faced was distinguishing modules in ROM and RAM from random junk. Their answer to this problem was structured memory modules. Module structure makes useful memory distinct from junk. That is the first use OS-9 makes of modules, but not the only use. Modules are central to the overall design of OS-9.

2.1 How Modules Are Identified

OS-9 must recognize modules accurately. It would be catastrophic if the kernel were inclined to find modules where there was only randomness. But since OS-9 is frequently called on to locate modules, the module-verification algorithm must detect non-modules quickly. The process OS-9 uses is something of a compromise between speed and accuracy. It verifies a module in stages. The first two stages quickly reject almost anything that isn't a module. The last stage is slow, but careful.

The beginning of a module is marked with a special two-byte code, hexadecimal $4AFC. It is possible that this code could occur somewhere other than the start of a module. To make certain that it has identified a module, and to learn more about the module (if that's what it is), OS-9 verifies that it fits a specified form.

The first 48 bytes in a module are called the module header. The header contains the sync bytes ($4AFC) and information about the module. There are twelve informational fields in the standard module header including the module's length, name, type, protection, and revision number. After these values is the second check on the validity of the module: the header parity word. This field contains the one's complement of the vertical parity of the preceding words (two-byte words) in the module header.

2.2 The Header Check

The header check is a simple form of Cyclic Redundancy Check (CRC). The vertical parity is taken by XOR'ing together the first 23 words (46 bytes) and the resulting 16-bit word is complemented. (See appendix B.)

When a number is XOR'ed with its one's complement the result is all one bits. This trick makes it easy to verify the header check value. All the words in the header, including the header parity, are exclusive or'ed together. If the result isn't

```
%11111111 11111111
```

something is wrong. Actually, the easiest way to do this is to take the one's complement of the vertical parity (XOR) of all 24 words in the header. This is the same operation that was used to generate the header parity except that we include the header parity with the rest of the header in the calculation. If the result isn't 0, the check fails.

The type of CRC used to calculate the header parity is only able to catch one-bit errors in the header. If the header parity is being verified over random data, there is one chance in 65535 that it will accept the data as a valid header. If it is run on a damaged header, it can detect some problems, but if two words are damaged, verification of the header parity can miss the problem. If the third and fourth words in the header are:

```
%01111000 01111000
```

and

```
%01010011 01010011
```

their exclusive or would be

```
%00101011 00101011
```

There are many other pairs of binary numbers that can be exclusive or'ed with each other to give the same result;

```
                        %00000000 00000000
                   XOR  %00101011 00101011
```

is a simple example. If only one word in the module header is changed, the header parity detects the fault, but if two words are changed there is a chance the damage will go undetected.

2.3 The Module CRC Bytes

It isn't likely for the header parity and the sync bytes to be correct by chance, but, even if they are, one more check is made before a block of memory is considered a module. OS-9 keeps a much more sophisticated three-byte CRC check of the entire module. The CRC check is run starting from the sync bytes for the length given in the module header. OS-9's CRC algorithm detects any reasonable form of damage, and the chances of it checking out over random data are one in about sixteen million. Taken together with the chances of the header parity verifying on random data, the probability of mistaking junk for a module is only about one in four billion.

There is no need to know the CRC algorithm. It is always best to use the code in OS-9 to generate and check CRCs via the `F$CRC`, `F$SetCRC`, and `F$VModul` system service requests (SVC's.) However, the mark of a good systems programmer is curiosity about just this kind of trivia, so here are some details about CRC calculation. For those of you who are content to let OS-9 handle this stuff, it is perfectly safe to skip ahead.

2.4 How the Module CRC Works

Cyclic Redundancy Checking (CRC) is an algorithm that detects errors in blocks of information. It detects errors more reliably than simple parity checking does, but it's substantially harder to do. In the CRC algorithm, the entire module to be checked is treated as one continuous stream of bits, a large binary number. First the number is shifted to the left enough to leave space for the CRC code at the low order end (in the case of OS-9 modules, a three byte left shift). The CRC code is the remainder after this number is divided by the "generating polynomial" using mod-2 division. (All operations are in base two, no borrowing or carrying.) The check bits are appended to the end of the module when the module is generated.

When the CRC algorithm is run on a bit stream including the CRC code, the resulting value is zero. Perhaps an example using standard decimal arithmetic would help (though, in fact, CRC is trickier in decimal).

If the generating polynomial is the number 13, the CRC code for the number 275101712 is 5:

> 275101712 must be shifted left two decimal digits giving 27510171200.
>
> Dividing by 13 gives 2116167015 remainder 5.
>
> Subtracting 5 from the original number gives 27510171195.
>
> Running the CRC algorithm on 27510171195 gives a CRC code of 0 because 2721017119500 is perfectly divisible by 13.

You probably noticed that the result of the CRC calculation in the decimal case wasn't the original number followed by the CRC code. When the operation is done in binary mod-2, everything works out smoothly. One important thing to notice about mod-2 arithmetic is that addition and subtraction give the same result. Since there are only the digits 0 and 1, and there is no carry or borrow:

$$\begin{array}{ccc} 1+1=0 & \text{and} & 1-1=0 \\ 1+0=1 & \text{and} & 1-0=1 \\ 0+0=0 & \text{and} & 0-0=0 \end{array}$$

Because of this peculiar behavior, subtraction is a useless operation in proper CRC calculation. Bearing this in mind, let's go a little deeper into the math.

Let the module be represented by the number *M*, the generating polynomial by *G*, the number of bits in the CRC code by *k*, and *X* by *M* shifted left *k* bits, then: +X/G = Q + R/G+ where *Q* is the quotient from the division and *R* is the remainder. +R = X - Q ×G+ or, since addition and subtraction are the same, +R = X + Q ×G+

The module with the CRC code attached is $V = X + R$. Since $X + R = Q \times G$, *V* is evenly divisible by *G*.

The algorithm actually used in OS-9 is slightly different from the standard CRC algorithm. Since division of large numbers is slow, OS-9 uses a special trick for finding the remainder of mod-2 division that uses mostly shift and XOR instructions. It also differs from the normal CRC algorithm in that the initial value for the CRC accumulator is \$ffffff in OS-9 instead of the normal \$000000, and the CRC code is complemented before it is used. The result of all the changes is that the CRC code for an intact module including CRC should be \$800fe3, the CRC generating polynomial, instead of \$000000.

2.5 Circumventing CRC Protection

Every module in memory is validated once before it is placed in the module directory. The validation takes place during bootstrap for ROMed modules and while a module is being loaded for other modules. Fortunately, OS-9 doesn't reverify the CRCs of modules after they are in the module directory. There are occasions when you will want

Figure 2.1: CRC Algorithm in C

A C-language implementation of the OS-9 CRC algorithm is shown below.

```
void crc(u_int16 *ptr, int32 n, u_int32 *crcacc)
{
    u_int32 tmp, tmp1, accum = *crcacc & 0x00ffffff;
    int16 tmp2;

    if(n & 1) {
        if(n == 1 && *(char*)ptr == '\0') {
            /* special case for one zero byte */
            tmp1 = tmp = (accum >> 16) & 0x0000ffff;
            accum <<= 8; tmp <<= 1;accum ^= tmp;
            tmp1 ^= tmp; tmp <<= 5; accum ^= tmp;
            tmp2 = tmp1; tmp2 <<= 2; tmp1 ^= tmp2;
            tmp2 = tmp1; tmp1 <<= 4; tmp2 ^= tmp1;
            if(tmp2 & 0x80) accum ^= 0x800021;
            accum &= 0x00ffffff; *crcacc = accum;
            return;
        }else exit(_errmsg(1, "odd count for crc"));
    }else n >>= 1;                                  /*convert byte to word count */
    while(n-->0) {
        tmp = *ptr++;                               /* get (next) data word */
        tmp <<= 8;                                  /* align data bit zero with CRC bit 0 */
        tmp ^= accum;                               /* get new data-CRC difference */
        tmp &= 0xffffff00;                          /* clear extraneous bits */
        accum <<= 16;                               /* shift current CRC; strip all but 23:16 */
        tmp >>= 2;                                  /* shift */
        accum ^= tmp;                               /* add input bit 17 net effect (over 16 shifts) */
        tmp >>= 5;
        accum ^= tmp;                               /* add input bit 22 net effect */
        tmp2 = tmp;                                 /* determine if even or odd number of bits */
        tmp >>= 1; tmp2 ^= tmp; tmp = tmp2;
        tmp <<= 2; tmp2 ^= tmp; tmp = tmp2;
        tmp <<= 4; tmp2 ^= tmp; tmp = tmp2;
        tmp <<= 8; tmp2 ^= tmp;
        if(tmp2 & 0x8000) accum ^= 0x800021;
        accum &= 0x00ffffff;                        /* clear extraneous bits */
    }
    *crcacc = accum;
}
```

to modify a module in memory, and generating a new CRC with each modification might be slow work.

In a system with a System Security Module (SSM,) write protected modules can only be changed by system state code or by ***ROMBug.*** Application programs, even ***debug*** and ***srcdbg,*** cannot store into protected modules.

Debug may be used to modify a module in memory. It is commonly used to apply patches and make ad hoc modifications to various modules. Changes made by the debugger cause the CRC value for a module to change without actually altering the CRC bytes. If the CRC for modified modules were reverified, the changes would cause the module to be rejected because of its incorrect CRC value.

Since a module is safe once it is in the module directory, modules can be modified either because of special circumstances (debugging) or as a matter of course, as is sometimes done with data modules.[1]

2.6 Module Types

Sync 4afc	System Revision	Module Size		Module Owner	Name Offset
Access Permissions	Type/ Language	Attr/ Revision	Edition	Usage	Symbol Table
					Parity
Execution Offset		Trap Execution Entry Point		Memory Size	Stack Size
Initialized Data Offset		Initialized Reference Offset		Initialization Execution Offset	Termination Execution Offset

The type byte in the module header can be used to specify any one of 256 module types, and the language byte specifies one of 256 languages. These values are used by the OS-9 kernel and the shell to place the module in the right place and do the right things with it.

Only seven of the available module languages have been defined. Of those seven, only three represent languages that are actually used; of those three, only two have any real effect on the function of the module. The language specification doesn't necessarily reflect the programming language used to generate the module. It indicates the actual language in the module. If someone ever comes out with a C compiler that generates Microware ***Basic*** I-Code, the module will be tagged as I-Code, not CCode.

The shell is the primary user of the language specification. When the shell prepares

[1] Modules may also be modified by defective programs. These problems are often subtle. They manifest as constants with strange values and other peculiar things. They are easy to find if you look for them. ***Ident*** reports that damaged modules have incorrect CRC. You can then save the damaged module and use ***cmp*** to compare the damaged module to the original. This reports the changes and their locations.

to execute a program, it checks the module's language. If the language is object code it forks the module. If it is Microware Basic I-Code the shell forks the ***Basic*** run time module, ***runb***, to run the I-Code. This makes it appear that the I-Code file is being directly executed.

The type specification might be better named Usage. The type byte specifies the purpose of the module. Most non-system modules are programs, but not all. If you write a matrix algebra package as a module that programs can link to when they need matrix algebra services, the module would probably be of either the Subroutine or TrapLib type.

The subroutine module type is a feature of OS-9 that hasn't caught on as well as it deserves. Subroutine modules contain subroutines. Programs can link to and call whatever subroutine modules they need. Basic intermediate-code modules are excellent examples of subroutine modules.

The better programming languages permit a programmer to build a program a piece at a time. These pieces are combined by the language or a link editor to form one program which can be loaded and executed. The reasons for modular design have been exhaustively discussed in the Computer Science literature. Let's just say that most people agree that it is a good way to create software.

If the pieces (called modules) used to build a program are written generally enough, they can be collected until programs can be built largely from existing modules. Like any subroutine library, this saves time. If you run several programs at the same time, the subroutine modules that they share only need to be in memory once. That saves memory.

If a program is written in one large file, changes to that program require that the entire program be recompiled. If, however, the program is written using files that are bound into an executable module by a linker, only the files containing changes need to be re-compiled. The linker still needs to consider all the files.

If the modules are bound while the program is executing, then only changed modules need be recompiled and linked. The old modules must be replaced with the new ones on disk or in memory, but that is the extent of the change. Sometimes modules in a running program can be replaced without stopping the program. I don't know of any way to rig a program so that modules actually being executed can be replaced, but with careful (slightly inefficient) programming a program can be designed so any module other than the one being executed can be replaced on the fly.

The TrapLib module type is another attempt by Microware to promote modular construction. They use the TrapLib mechanism heavily for I/O and floating point libraries. Traplib modules are much like subroutine modules. They serve as globally-accessible collections of services. Traplib modules are distinguished from subroutine modules by their access method. Trap handlers are easier to use (and less efficient) than subroutine modules.

Four special module types are used for OS-9 itself. The OS-9 kernel and the SSM module are examples of system modules. File managers like Pipeman, SCF, and RBF are file manager modules. Modules like rb1772 and sc68681 are device drivers, and device descriptors like term and D0 have their own type.

The system module types mark modules that belong in the system area and give an extra check on the identity of a module.

Three module type/language combinations are special in that they can't be executed. The device descriptors don't contain any executable instructions, just lots of information. The init module (there's only one) contains most of the constants that configure OS-9. All other non-executable modules are data modules. The data module type can be used for any module that you don't intend to have executed. Data modules are used to store global data and configuration information for user programs.

2.7 Module Security

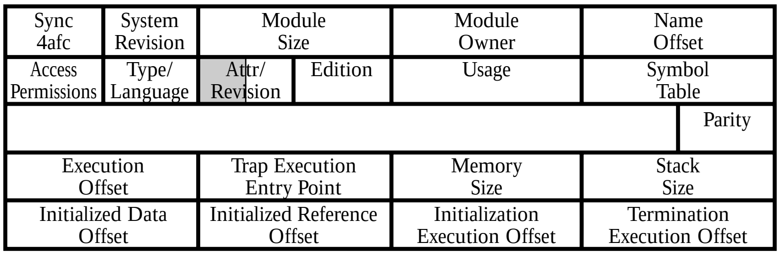
Four values are used for module security. The file from which the module was loaded contributes the file owner and the file access permissions. The module header contributes the module's owner and the module access permissions. The module owner and access modes act somewhat like file access permissions. On systems without memory protection hardware, OS-9's ability to protect modules against invalid access once they are in memory is limited, but a careful programmer on a system with protected memory can make his modules about as secure as he wants.

The file the module came from is important when the `F$SUser` SVC is used. Processes start with the user number of the process that forked them, but OS-9 supplies a controlled way for a process to change its user number. Any process may use the `F$SUser` SVC to set the user number it is running under to the module's owner. Only processes running under the super user ID can reach arbitrary user IDs.

Do not rely on this protection to protect users from hostile programmers. A programmer can write a program that does an `F$SUser` to whatever number he wants by putting the desired value in the module-owner field when he constructs the module. There is a measure of protection against this trick. Modules owned by the super user must be loaded from files owned by the super user.

To further protect against malicious programmers, the kernel saves a value calculated as a function of the bytes in each module header in the module directory entry for that module. If this was not done, a programmer could load a module, then modify the user, type, and revision number of the module as required. Any module in a system without SSM or with the writable attribute can have its security attributes modified this way, but the module directory is a system data structure and, at least in systems with SSM, user processes cannot update system data structures. The result is that module headers can be updated, but any module modified in that way becomes unusable. It is impossible to link to a module with a modified header.

2.8 The Module Attribute Byte



Storage attributes of the module are coded in the module attribute byte. Three attributes are in common use.

ReEnt The high-order bit (bit 7) in the attribute byte denotes the reentrant attribute.

Ghost Bit 6 is used for the ghost module (also called sticky) capability. Unless ghosting is disabled by setting the NoGhost bit in the M$Compat byte in the init module, modules with the ghost capability remain in memory when their link count goes to zero. They stay in memory until their link count goes to –1 or the memory is required for some other purpose.

Don't use the ghost attribute on programs that are under development. Ghosted program modules remain in memory and later revisions have to be loaded explicitly. It is easy to forget that a module is ghosted and wonder why revisions don't seem to take effect.

SupStat Bit 5 indicates that the module must run in supervisor state.

Some systems may use another bit to indicate that the module is write protected.

2.8.1 Reentrant Modules

Most modules under OS-9 are reentrant. A typical system could run for years without executing a non-reentrant module. All the operating system modules are reentrant, and every compiler distributed by Microware generates reentrant code unless it is badly abused. A programmer can, of course, easily generate a non-reentrant module with the assembler. If a program is written so that it modifies constants that the compiler stores in the module, it will not be reentrant—and it will, very likely, fail on a system with memory protection.

A reentrant module can be used by several different processes at the same time without any of them knowing that they are sharing the module. The only requirement for this (under OS-9) is that the module must not alter itself.

Reentrancy is a device which can save large amounts of memory but only if reentrant modules are well used. Some modules, like ***umacs***, are frequently used by more than one process at a time. This saves about 42k for each process after the first because only one copy of ***umacs*** needs to be loaded for all the processes. Most modules aren't as widely used as ***umacs***. Single-module programs are usually too specialized to be of general interest. These programs are probably full of code that would be useful to other programs, but there is no way to share it.

A well-designed modular program is built of a set of modules, each as independent of the others as possible and each performing one task or a closely related group of tasks. Modules that are part of a well-modularized program are very likely to be useful to other programs. If the modules are reentrant, only one copy of a module is stored in memory regardless of the number of programs using the module.

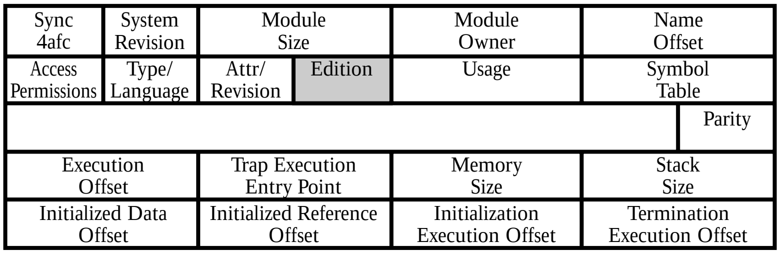
2.9 The Module Revision Number

Sync 4afc	System Revision	Module Size		Module Owner	Name Offset
Access Permissions	Type/ Language	Attr/ Revision	Edition	Usage	Symbol Table
					Parity
Execution Offset		Trap Execution Entry Point		Memory Size	Stack Size
Initialized Data Offset		Initialized Reference Offset		Initialization Execution Offset	Termination Execution Offset

The byte after the module attribute byte in the module header is the revision byte. The revision number has no influence on what is done with the module once it is loaded—revision two is treated like revision one. It is only important during the actual loading process. A module already in memory won't be replaced by another module loaded from disk unless the new module has a higher revision number.

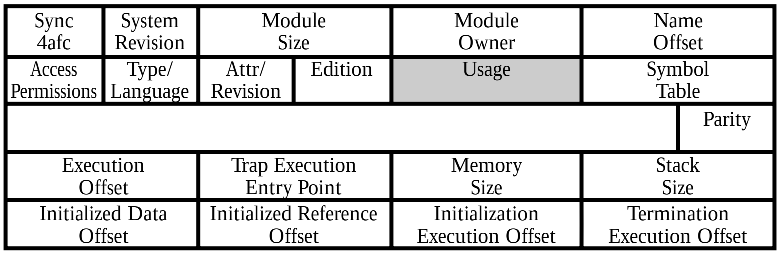
Revision numbers aren't heavily used on disk-based systems. If a module is loaded with the `F$Load` SVC, it can be unlinked and replaced. ROM-based systems require revision numbers. A module that is stored in ROM can only be replaced by re-blasting the ROM or superseding the module with a module having a greater revision number. Revision numbers are also useful for development work on modules that must be included in the boot file. Boot modules cannot be removed from memory, so they can only be replaced by rebooting the system or loading a module with a higher revision number.

2.10 The Module Edition Number



The module edition number is stored in the word after the revision number. OS-9 ignores the module edition number, but it is good policy to increment the value in this field every time you finish an update to the module. Since it's a word, you can update the module many times before you run out of new edition numbers. The ***ident*** utility displays the edition number along with most of the other information in a module's header. ***Ident,*** in combination with conscientious use of the edition number field, is a good way to determine whether a module is the latest version.

2.11 The Module Usage Field



The module usage field has great promise, but its use isn't defined yet. We do know that the module usage is the offset from the beginning of the module to something that describes the usage of the program, but we can only speculate about what will describe the usage. It could be as simple as the string the system commands display when you invoke them with a "-?" argument. It could be as complicated as special code that explains the usage of each module in some elaborate way.

Figure 2.2: Module Directory Entry

Module pointer	Module group pointer	
Module group size	Link count	Header chk

2.12 The Debugging Symbol Table

Sync 4afc	System Revision	Module Size		Module Owner	Name Offset
Access Permissions	Type/ Language	Attr/ Revision	Edition	Usage	Symbol Table
					Parity
Execution Offset		Trap Execution Entry Point		Memory Size	Stack Size
Initialized Data Offset		Initialized Reference Offset		Initialization Execution Offset	Termination Execution Offset

Modules are at the root of OS-9. Designing the module header was one of the first steps in Microware's design of OS-9. The debugger wasn't written until much later. There is a field in the module header that might have pointed at symbolic information for the debugger. When the debugger was written, they discovered that it was more efficient to put this information in a separate module. The M$Symbol field is used in the STB modules that contain symbol information used by debuggers, but otherwise the field is unused.

2.13 The Module Directory

OS-9 maintains the module directory, which is a list of all the modules in memory. There are only five fields in each module directory entry. Most of the information about a module is in the module header. A module directory entry contains the information about a module that is determined when the module is loaded (such as the module's address).

The first field in a module directory entry is a pointer to the module header; it is followed by a pointer to the first module in the "module group" containing the module.

If a module is loaded by itself, its module pointer has the same value as the module group pointer. When you load a file with several modules in it, OS-9 combines them into a module group, and stores the length of the group and a pointer to the start of the group in the module directory entry for each module in the group. This feature is intended to conserve memory. When modules are loaded separately they must each start on a memory allocation boundary, but when they are combined in a file they are loaded into contiguous memory. With the standard memory allocation granularity of 16 bytes, the memory saved by module groups is small.[2] Incidental advantages of module groups are usually more significant:

- The single large read used to read a module group is faster than multiple opens and reads that would be done for a collection of modules in separate files.
- A module group loads into one chunk of memory. Modules loaded separately use separate blocks of memory, potentially causing memory fragmentation.
- Modules in a module group stay in memory until all the modules in the group have a reference count of zero.

The next field in a module directory entry is a two-byte module link count. Each time a process gets a pointer to the module, the link count is incremented. Each time the module is unlinked or unloaded, the link count is decremented. No module is removed from memory unless its link count is zero (–1 for ghost modules). However, zeroing a module's link count isn't a sure way to remove it from memory. When modules are collected in a group, they must all be removed at once. If any module in a group has a non-zero link count, the group remains in memory.

A value computed from the values in the module header is also stored in the module directory. This makes it difficult for programs to modify the permissions and owner in their header and violate module security. The value is computed and recorded when the module is loaded, and checked when the module is linked.

2.13.1 Unlink Protection

Prior to release 2.4.3 of OS-9, only a module's access protection kept it from being removed from memory by F$UnLink. The results were particularly unfortunate when someone would inadvertently unlink a trap handler like cio, or a program module that was in use at the time. In release 2.4.3, the unlink SVC became substantially more careful. It looks at each process descriptor checking the program module and trap handler modules for the process against the module that is being unlinked. If a module is referenced by a process descriptor, it cannot be fully unlinked.

2.14 How Modules Are Generated

The easiest and most common way to generate modules is with a compiler. The Microware Basic pack instruction turns Basic procedures into subroutine modules of Basic I-Code. Languages that compile to native code produce program modules

[2] Systems with an MMU and SSM software often use a 4 kilobyte memory allocation granularity. This makes module groups a more useful memory-saving tool in systems with SSM.

of 68000 object-code. Assemblers are also used to produce program modules, but assemblers being what they are, you can produce any type of module with them.

The assembler doesn't actually build modules. It creates relocatable object files that the linker combines into a module. The constants and machine instructions are passed from the assembler through the linker to the final module without modification, except that no promises are made about the order in which the linker combines things. The only time you'll feel concerned about this is when you want to use a short `bsr` instruction between program sections (psects). The linker tends to combine code from different files in the order it sees them, but that may change.

The assembler psect directive transmits information to the linker that it uses to construct the module header. The psect statement can have six or seven arguments:

1. The first argument is the psect name. The linker uses `psect` names in error messages to identify the source of errors.

2. The module type/language word. The module type must be shifted left by eight bits before it is combined with the language. This field has two purposes. If it is zero, the psect is not the main psect. If it is non-zero, the value is used to set the type and language bytes in the module header. Magic numbers work in the type/language field, but people who can't read OS-9 codes like English will understand you better if you use constant names from the sys.l and usr.l libraries like this:

   ```
   TypeLang  equu    (Prgrm«8)+Objct
             psect   Silly,TypeLang, ...
   ```

   The (Prgrm«8) means that the assembler should take the value of the constant Prgrm and shift it eight bits to the left.

3. The module attribute/revision word. This trick of squeezing two one-byte fields into a word is left over from OS-9/6809. There, these two values shared a byte. Now they have a byte each, but the assembler hasn't caught up yet.

4. The module edition number is for documentation only. The ***ident*** command displays it, but other than that, a module's edition number is ignored by OS-9.

5. The stacksize field is your calculation of the amount of stack space that this psect might use. The linker adds the stacksize fields from the psects it combines into a module to get a value for the stacksize field in the module header. If a psect can use several different amounts of stack space depending on the data it gets, use the maximum.

6. The entry point field is the offset from the beginning of the psect to the entry point for the module. This field should only be non-zero for the main module.

7. The trapent field should never be zero. It should only be used on the main `psect`, and only if you have written code to deal with uninitialized trap exceptions (see chapter 14). If you don't use this field, stop with six arguments for the psect directive.

The beginning of a file containing a program's main psect might look something like this:

```
          ttl    example program
          nam    example
          use    <oskdefs.d>
TypeLang  equ    (Prgrm<< 8)+Objct
AttrRev   equ    (ReEnt<< 8)+1
Edition   equ    1
StackMax  equ    249
          psect  example,TypeLang,AttrRev,Edition,StackMax,Entry
          ...
Entry
```

A subroutine psect is simpler:

```
          psect  sub1,0,0,0,273,0
```

Only the name and stacksize fields need to be filled in.

2.15 SVC's that Deal with Modules

The `F$Load` SVC reads modules from a file whose pathlist is passed to the SVC as a parameter. It loads all the modules in the specified file into memory and adds them to the module directory, but only the first module in the file has its link count incremented. The `F$Load` service request returns the same values in its registers that an `F$Link` on the first module in the file would have; that is, the module type/language word of the first module in the D0 register, the module attributes/revision word in D1, a pointer just past the path list in A0, the address of the module entry point in A1, and the address of the module header in A2.

The standard way to locate a module in memory is the `F$Link` SVC. It takes as input the address of a string containing the name of the module you want to find and the type/language of the module. The name of the module must start with a number or alphabetic character. It must be terminated with the OS-9 standard ending, a null byte. Use a C string "Modulename" or `dc.b` with an explicit zero to do this:

```
          dc.b   "Modulename",0
```

If a type/language is specified by loading its value into register D0 before calling F$Link, link will only find a module that matches both the requested name and the requested type/language. If you don't want to specify one of these values, use a zero. For example, the hex value $0100, the type/language code for program modules with no language specified, matches a program module in any language.

The type/language and attribute/revision bytes for a module found by the F$Link SVC are returned in the D0 and D1 registers. The A0 register is advanced past the module name it pointed at before the SVC. The address of the module's header is returned in A2 and the entry address in A1.

The F$UnLink SVC is used to decrement a module's link count. If all the modules in the module's group are ready to be released (link count of −1 for ghost modules, zero for other modules), F$UnLink releases the module group's memory and the module directory entries for the modules in the group. This SVC only requires the address of the module header for the module to be unlinked. Remember to save the address of the module header when the module is linked.

F$UnLoad has the same effect as F$UnLink, but it uses the module's name and language/type to locate it instead of a pointer to the module's header. This call is important when you want to remove a module that has extra links. If every program that has a link to a module remembers to unlink it, the module will disappear when no process is using it. If a process doesn't unlink a module as many times as it links the module (the link command is a program that does this) the F$UnLink SVC can't zero the module's link count without cheating.

When you unlink a module it is mapped out of your address space. Your pointer to the module header isn't good any more. The only way to unlink it another time is to link it back into your address space then unlink it. You can't decrease the module's link count more than you increase it.[3]

The F$UnLoad SVC lets you decrease a module's link count without linking to it. Using this SVC, programs can zero a module's link count without hurting their portability to systems with memory protection.

F$CRC is used to calculate the CRC for a module, or, for that matter, anything else that needs a CRC. It uses the address of the block of data, and the length of the block. It leaves the CRC value for the data in D1. If it isn't convenient to calculate the CRC on an entire block of memory at once, F$CRC can be used on sections of the data provided that the sections are in order starting with the first part of the block. The D1 register is used to accumulate the CRC value, so it should be initialized to $ffffffff before the first call to F$CRC and then left alone until the entire block has been passed through F$CRC.

[3] Since OS-9/68000 does not use dynamic address translation, the module's address is actually still correct, but if you play by the rules, you should treat it as invalid.

If you are using F$CRC to validate a module, accumulate the CRC through the entire module including its CRC bytes. The accumulator will contain the generating polynomial[4] if the CRC code checks out.

If you want to generate a CRC code for a block of memory, run F$CRC over the data, and complement[5] the generated CRC. The resulting value can be concatenated to the block of memory to give the block a valid CRC.

There is a special SVC just for updating a module's header parity and CRC. The F$SetCRC SVC takes a pointer to a module in A0 and doesn't return anything unless it returns an error code.

The service request that verifies a module and places it in the module directory is F$VModul. It is a system mode request. It takes the address of the new module in A0, and the module's group ID. It returns a pointer to the module's module directory entry.

The F$DatMod SVC builds data modules on the fly. You tell it the amount of data you want to store in the module, the name you want it to have, the desired attribute/revision word, and the access permission you want the module to have. The F$DatMod call builds the module in memory, registers it with the system, and returns the same values you would get from a F$Link SVC.

Data modules use the execution-offset field in the module header as the data offset. This field gives the offset from the beginning of the module to the first byte of the data area. The F$DatMod and F$Link SVC's leave the A1 register pointing to the data area in the data module.

[4] The value of the CRC generating polynomial (CRC) is $00800fe3.

[5] Use the 68000 instruction not to complement the CRC code.

Chapter 3

Memory

In this chapter we discuss prudent memory management.

OS-9 supervises the distribution of memory to programs. Sometimes it may seem that OS-9 has taken memory allocation completely out of your hands, but, in fact, there is a lot you can do about the way memory is used.

The memory chip manufacturers have cut the price of memory dramatically over the years.[1] System designers have responded by designing each new generation of computer with a larger memory than the previous generation. Software designers have also noticed the availability of large memories and joyfully created software that requires at least as much memory as they expect to find. Perhaps because of this interaction between hardware and software, it is axiomatic that a computer will never have enough memory.

Since you will never have a computer with enough memory, it is always important to make the most of the memory you have. Under OS-9 that means using reentrant modules, using memory where it does the most good, and worrying about memory fragmentation.

3.1 Reentrant Modules

The most important step to take toward conserving memory is to use reentrant modules whenever possible. It is often worth considerable trouble to make a module reentrant, but reentrancy is seldom a difficult goal. The basic rules for reentrancy are simple:

- A reentrant program must base all its variables off address registers.

[1] This sentence has been in editions of this book since the days when OS-9 was only available for 6809s. It is at least as true today as it was then.

- PC-relative values and absolute addresses may only be used as constants.
- Programs that modify themselves are strictly out of the question.

The modules you are most likely to create will contain programs either in intermediate code (like Microware Basic I-Code) or in 68000 object code. The Microware C compiler creates reentrant code by default, as do all high-level languages for OS-9.[2] If you write in assembler you can do whatever you want, including writing non-reentrant code.

The advantage of reentrant modules is that any number of processes can share them. Each process must have its own data storage, but many processes can share the module itself. Not having to store a separate copy of the program for each process can save significant amounts of memory. As an example, note that if the C compiler components weren't reentrant, each process using the compiler would start by requiring a large block of memory just for its copy of the compiler modules. As it is, even medium-sized systems can run three or four compiles concurrently.

Making a module reentrant is easy. Making a module general enough that several processes might want to use it concurrently is harder. Important system programs like editors and shells are especially carefully designed for general appeal. The designers know those programs will be heavily used.

It isn't likely that most full-blown programs will be used by several processes unless the system is dedicated to the task performed by the program. However, there are some operations that many programs have in common: formatting output, math, validating input, formatting the screen, and handling database files are some examples. If all these functions are built into a single module, a program must incorporate the entire package if it wants any function from the module. If separate modules are built to do each of these operations, some of them might serve several different programs, and each program can get the services it needs without using memory for a whole class of services it does not need. OS-9 makes it easy for a program to collect a group of modules with the F$Link and F$TLink Service Calls (SVC's).[3]

3.2 Memory Fragmentation

Memory fragmentation is a problem that serious OS-9 users must learn to handle. OS-9 Level Two for the 6809 uses Dynamic Address Translation to make memory

[2] This isn't strictly true. You can write a non-reentrant program in C by modifying values that the compiler assumes are constant. The compiler permits this, but a system with memory protection may give bus errors when it attempts to run the program.

[3]Trap handlers are an easy way to share code. OS-9 comes with trap handler modules for mathematical functions and print formatting. Traps are not the best way to access shared resources, but they are easy to use.

fragmentation irrelevant, but there is no such facility for OS-9 on 68000-family processors. These systems can be configured with enough memory to solve the problem without address translation.

Memory fragmentation only becomes a problem when the available free memory is split into so many pieces that OS-9 can't find enough memory in one block to satisfy a program's memory request. This is a serious problem, and is dealt with in more depth in chapters 4 and 5. The simple solution to memory fragmentation problems is to kill processes and unlink modules, starting with the ones you can spare most easily and continuing until there is enough contiguous free memory. The ***mfree*** command tells you how many blocks of free memory you have, and how big they are.

The OS-9 kernel and its satellite components (like file managers and device drivers) allocate memory as they require it. File managers and device drivers may allocate memory when a device is attached (initialized). Since this memory stays allocated until the device is detached, it can cause serious long-term fragmentation. Attaching every standard device when the system is booted is a good policy. A command line like:

```
$ iniz dd h0 d0 t1 t2 t3 r0
```

early in the startup file attaches the devices while there is free memory near the top of RAM. Devices that are attached later (by opening a file on a device that hasn't been used yet), are likely to allocate their memory near the middle of memory. This type of fragmentation is hard to control except by getting the system fully initialized while memory is mostly empty.

3.3 Careful Use of Memory

There are some ways to waste memory that (I think) can only be done intentionally. The best example is the ***sleep*** command. ***Sleep*** takes any memory it is given out of circulation for a specified interval. You can be certain sleep doesn't run any faster or better with more memory.

If you want to waste over 48 kilobytes of memory for some reason, use:

```
$ sleep 10000 #48&
```

The above command takes 72 kilobytes of memory[4] out of circulation for the duration of the sleep.

Programs can be given memory that they cannot use, or don't even notice. This is a subtle but effective way to waste memory. It is easy to allocate extra memory

[4] ***Sleep***'s requirement for 72 kilobytes is specific to edition 17 of ***sleep*** and the memory allocation parameters on my system. 48 kilobytes of it is governed by the shell command line, and 24 kilobytes of the memory is the normal requirement of ***sleep***.

to a program with the # ***shell*** option, but many programs ignore extra stack space. Current-generation OS-9 software requests adequate stack space by default. The only time extra stack space should be required is for programs with recursive algorithms that will recurse more deeply than the programmer expected. Programs that don't allocate dynamic memory from the block of storage given to them by the shell may use kernel system memory requests for their dynamic memory requirements. The amount of space they allocate can usually be controlled with a –b command-line option.

In general, give a program extra memory only if you *know* it will help. The ***copy*** command is a good example. Everyone knows ***copy*** runs better if it is given extra memory. No question, it does. But how much better it runs depends on your disk controller, disk hardware, and what else is going on in your system. Extra memory usually makes a large difference in the performance of ***copy***, but sometimes it will make almost no difference. It is worth experimentation.

Text editors usually have reliable memory requirements. They can only load as much of a file into memory as fits in the memory you give them. Even editors that can cleverly leave part of the file on disk when they can't fit the entire file in memory run slowly or have difficulties with search and replace commands when part of the file remains on disk.

Some programs, like Microware Basic, make it very clear to you when they need more memory. They don't care how much memory they have available to them, provided it is enough. Programs like ***backup*** and ***copy*** run faster with extra memory, but how much faster depends your system. If you use the commands a lot and care about conservation of memory, it would be worth your time to make some tests to determine how the amount of memory allocated to a program affects the progam's speed in your environment.

3.4 Dynamic Memory Allocation

In one case wasting memory is necessary. If a program running under OS-9 wants to call for an enlarged data/stack allocation data memory, it should call for the memory in the module header even if it won't use the memory until late in the program execution. The stack and data memory cannot grow during program execution.

A program can *request* either of two kinds of memory allocation:

- a contiguous extension of its data area,
- a new block of memory allocated wherever there is room.

However, only requests for new blocks of memory will succeed. The discontinuous blocks of memory are called system memory.

System memory may be allocated at any time, but when possible all memory should be allocated soon after a process starts. The reasons to allocate all your system memory when the program starts are performance and reliability. Memory allocation and deallocation are comparatively slow system calls. It is best for programs to deal with memory allocation before commencing real-time operation. Allocating memory during initialization also prevents the program from terminating for lack of memory after running for a while. This makes error recovery easier.

Ghost modules can save time by keeping memory full of modules, but programs that use a large part of the system's memory can cause an interesting type of fragmentation when ghost modules are in the system. Ghost modules remain in memory even when their link count goes to zero. They are available in memory for subsequent use, but OS-9 removes them if a program needs their memory. If you run a program that allocates more than about half your system's memory for data, ghost modules can cause a program to make its own fragmentation.

- A program module is loaded. (Let's call it LaTeX.) There is room for it below the current batch of ghost modules, so OS-9 loads it without removing any ghost modules.

- Fork allocates memory for the stack, and later the program requests system memory.

- When it finds that there is insufficient memory to fill a memory request, OS-9 removes ghost modules, but it won't help.

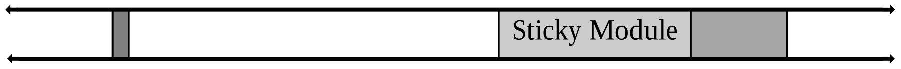
- The free memory is divided around the LaTeX program module. The module is located below the memory that was filled with ghost modules. It divides the available memory into two blocks.

The cure for a ghost-fragmentation problem is to delete the program module, LaTeX, and start over. By deleting the program module and loading it again, you move it up toward high memory and leave a large block of memory below it.

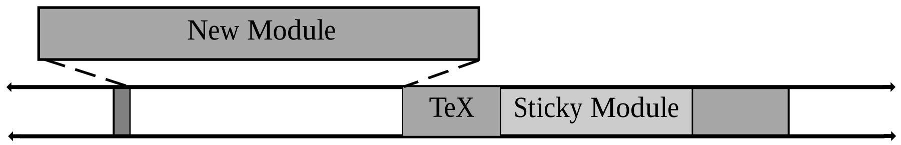
If you don't push your system, you probably won't have trouble with memory. Fragmentation seldom becomes an issue unless several processes are running simultaneously. Even if you run several processes, fragmentation is unlikely unless the processes are running concurrently and allocating and freeing memory. Systems that set up a collection of processes, allocate memory, and run for a long time are fairly immune to fragmentation.

The final cure for memory fragmentation is plenty of RAM. I have never experienced fragmentation, even with a complex process environment and continuous memory allocation and deallocation, when the system has enough memory to always have twice as much free RAM as I needed. For a typical assembly language development

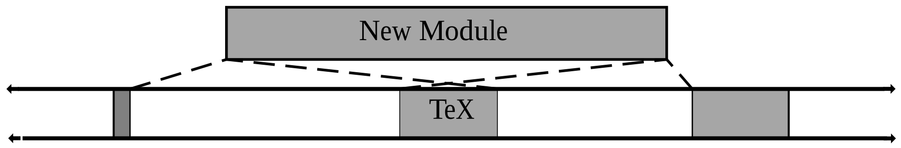
Figure 3.1: Ghost Fragmentation



Here's the initial state of memory. Next, a small module named TeX is loaded successfully.



Now, a larger module fails to load because there isn't enough space. OS-9 removes the sticky module to make more space.



OS-9 tries to load the larger module again, but removing the sticky module did not increase the amount of contiguous free space.

system, 300 to 400 kilobytes of free memory is usually enough. For Ultra-C programming, four to eight megabytes is enough for reasonable-sized programs. With X, Ultra-C, and complex programs with interprocedural optimization, 16 to 32 megabytes is required.

Chapter 4

OS-9 Memory Management

This chapter discusses the mechanisms that support OS-9 memory management and the realization of those mechanisms in the OS-9 kernel.

Any operating system that permits more than one program to run at the same time needs a way of dividing the system's memory between the programs. OS-9 uses a dynamic memory management scheme. Instead of jumping right into OS-9 memory management, we'll start with some simpler memory management schemes and work up to OS-9's techniques gradually.

4.1 The Theoretical Base

Managing a computer's memory is a lot like managing on-street parking. A system's memory, like curb space, must be divided among users. It is good to use memory (or curb space) as efficiently as possible, but keeping the amount of supervision required to a minimum is also important.

Of course, the simplest way to handle system memory is to ignore the problem. Operating systems that only deal with a single process don't need to concern themselves with memory. There are many examples of operating systems that don't provide any memory management facilities, including PC-DOS, CP/M, and FLEX.

4.1.1 Fixed Partitioned Memory

Another simple way to allocate memory is to divide it into several regions called partitions and allocate a partition to each process. The partitions are constructed when the computer is started and not changed except by restarting the operating system. Because of the permanent nature of the partitions, this method of memory management is called Fixed Partition memory allocation. This is analogous to the most common way of allocating parking space—marking off parking places with lines on the pavement and allowing one car in each place.

It is simplest if all partitions are the same size, but it may be better to make them different. If they are all the same size, a process can either fit in any partition or none of them. Since all partitions are the same, the operating system can use any convenient rule to assign them.

Partitions of a variety of sizes accomodate processes that require lots of memory without requiring all the partitions to be big enough to hold them. The analogy in the parking world would be to have several different sized spaces. Some suitable for cars, others for trucks.

This enhancement to the partitioned memory system causes lots of trouble. If all the small partitions are full, can a process use a partition that's too large for it, or should it wait for a small partition to free up? How many different sizes of partition should be used to get the best possible use of memory? Think of the parking situation again. If all the car slots are full, should a car be permitted to use a truck place? Is it a good idea to have special motorcycle places? How about compact car parking spaces? Remember that small spaces are efficient ways to store small vehicles, but they are entirely wasted when small vehicles don't need to park.

An operating system that uses partitioned memory is easy to write, but it tends to waste memory. Attempting to fix the problem makes this method complicated without fixing anything.

There are some special cases where partitioned memory is fine. Many operating systems set aside a special area in memory for small utility programs. That is a trivial example of partitioned memory. It is wasted space much of the time, but it is a small partition so the waste is minimal. These small partitions are especially useful for running programs like print spoolers that are meant to be tucked out of the way.

4.1.2 Dynamic Allocation

If fixed partitions aren't good enough, memory can be allocated in suitable chunks as it is needed. This is a good idea, but it's not as easy as it might sound. Let's move right to the parking problem. This system is like having a parking attendant who directs vehicles to the right spot without any lines on the pavement. If there are a variety of different sized vehicles, the attendant should be able to use his freedom to pack them more efficiently than he could if he had to place them in pre-marked areas.

Things look very good as the first batch of cars and trucks are parked, but after a few leave and others arrive trouble starts. Say the street is filled up end to end, then five small cars leave from five separate locations. Now a small truck arrives. It is small enough to fit in much less than the amount of space just vacated by the five cars, but, since the five empty slots are in five different places, they are useless to the truck. If a truck leaves and a car gets to the place first, it will take up some part of the space. Most of the space is still there, but it isn't any good for the next truck to come by.

There are two standard ways of managing memory when it is isn't partitioned in advance. They are called first-fit and best-fit.

4.1.3 First-Fit Allocation

First-fit allocation is the simplest method. The operating system chooses the first block of memory at least as big as the amount requested. It allocates as much of the block as required leaving the rest as a smaller unallocated block. Unfortunately this tends to use up big blocks of memory leaving lots of little chunks that can only be used to satisfy small requests.

4.1.4 Best-Fit Allocation

Best-fit requires the operating system to do more work, but it does a better job than first-fit of keeping large blocks of memory for programs that really need them. In best-fit allocation, the operating system scans through its available memory looking for the block that fits the request with the least memory left over. This method leaves slivers of unallocated memory around, but it preserves large blocks of memory by refusing to use them as long as any smaller blocks will do the job.

There are other methods. The oddest one I know of is worst-fit allocation. Worst-fit allocations are always made from the largest block of storage. The reasoning is that the fragment of the large block that is left over after the allocation is made will be larger, and therefore more useful than it would be if the allocation were made out of a smaller block. This policy amounts to punishing large blocks of free memory. For typical sequences of memory allocation and free operations, the result is a lot of roughly equal-sized blocks of free memory.

Most people use first-fit to manage on-street parking when there is no attendant. Those whose parallel parking skills aren't so good lean toward a worst-fit method—perhaps that's why on-street parking is usually partitioned. If drivers park in the first space they see that is long enough for their car, they are using first-fit. Those who go out of their way to find a large space are using a modified worst-fit algorithm.

Best-fit probably wouldn't work without an attendant. It requires each driver to check all empty parking places and pick the spot with the most precise fit.

4.2 OS-9 Memory Management

To bring reality in for a moment, OS-9 uses first-fit allocation to manage its memory. Microware added a special twist by having module storage and system memory requests start from high memory, and data storage allocations start in low memory. You can watch it in action by starting several programs running in the background. The easiest program to use space with is ***sleep***. ***Mfree*** reports on where free space is located, and ***mdir*** can list the addresses where modules reside. There is no standard command[1] in OS-9 that directly reports the data space associated with each process so this must be inferred from ***mfree***'s output.

The following example is taken from a 2-Megabyte GMX Micro-20. It gives different numbers on other hardware or with another software configuration, but it should have the same flavor on any configuration.

First set up a special startup file:

```
-np
-nt
load utils
link shell cio
setime -s
iniz d0 h0
```

Utils is a file containing ***link***, ***setime***, ***date***, ***mdir***, ***mfree***, ***sleep***, and ***iniz***. This file contains all the modules we will use in this experiment. Loading them all from one file puts them in a contiguous block of memory and avoids extraneous memory fragmentation.

Now reboot the system to get a clean memory map, and use the ***mdir –e*** command. Examine the module addresses in the first column of its output. The modules that were loaded as part of the OS-9 bootstrap, from OS9Boot, probably appear all together, and probably at low addresses. Modules loaded from startup are at higher addresses. You should find all the modules loaded from Utils in a contiguous block of memory and the other modules used in startup, ***shell cio*** and ***load***, nearby. ***Load*** is in memory as a ghost module. It was used by the startup script, and the memory has not been required for anything else yet.

After removing from the output of ***mdir –e*** all the modules loaded from the OS9Boot file, we are left with the modules shown in figure 4.1.

Now use ***mfree –e*** to get a better idea of the layout of memory. The output is shown in figure 4.2.

Modules fill 121,350 bytes of memory plus an extra 12 bytes to bring the size of the boot file up to a multiple of 256 bytes, and 238 bytes to bring the size of Utils up to a multiple of 256 bytes. Since there are 1859 kilobytes free, there are $2044k - 1859k - 118.75k = 66.25k$ bytes used to run ***mdir*** and for system data structures.

[1]The ***maps*** utility does show the memory associated with each process. It is included with any system that has SSM.

Figure 4.1: MDir of Modules Loaded at Startup

```
Addr        Size     Owner    Perm Type Revs  Ed #  Lnk  Mod-
ule name
--------  -------- --------- ---- ---- ---- ----- ----- ----------
-
001f7530    20754     1.0    0555 Prog c001    52     2 shell
001f5720     3284     1.0    0555 Prog c001    16     0 load
001f07d0    17732     1.0    0555 Trap c009     6     2 cio
001e9210     3082     1.0    0555 Prog c001    15     1 link
001e9e1a     4702     1.0    0555 Prog c001    24     0 setime
001eb078     2824     1.0    0555 Prog c001    17     0 date
001ebb80     5214     1.0    0555 Prog c001    20     1 mdir
001ecfde     2736     1.0    0555 Prog c001    15     0 mfree
001eda8e     3312     1.0    0555 Prog c001    13     0 sleep
001ee77e     2426     1.0    0555 Prog c001    15     0 iniz
```

Now let's confuse issues by starting a bunch of ***sleep***'s for different lengths of time with different memory requirements[2]. The best way to start several processes quickly is with a shell script. The following typescript records the process of creating a shell script with the ***build*** utility and executing it by giving its name to the shell:

```
$ build tmp
? sleep 1000 #460k&
? sleep 10000 #20k&
? sleep 1000 #350k&
? sleep 10000 #20k&
? sleep 1000 #480k&
? sleep 10000 #20k&
? <esc>
$ tmp
+5
+6
+7
+8
+9
+10
```

Immediately after all the ***sleep***'s start, memory is in the state shown in figure 4.3.

When the three shorter ***sleep***'s end, memory has changed to the state shown in figure 4.4.

[2] The memory requirement of ***sleep*** can be specified by the # shell option.

Figure 4.2: MFree at Startup

```
Minimum allocation size:       0.25 K-bytes
Total RAM at startup:       2044.00 K-bytes
Current total free RAM:     1859.00 K-bytes

Free memory map:

    Segment Address        Size of Segment
   -----------------   --------------------------
       $15700          $200           0.50 K-bytes
       $17700          $1D0600     1857.50 K-bytes
       $1F4E00         $100           0.25 K-bytes
       $1F6400         $100           0.25 K-bytes
       $1FC700         $200           0.50 K-bytes
```

There are 1761.50 kilobytes free, but if you try to run a program that needs more than 484.25 kilobytes, it will not be able to find sufficient memory. Try it:

```
$ sleep 4 #500k
Error #000:237
```

Error number 237 is an “insufficient contiguous memory” error. It is telling us that OS-9 can’t find enough memory in one block to satisfy our request. Since the problem took place while OS-9 was trying to allocate memory for a process it was forking, it gave a 237 error instead of the usual error 207.

We can use this setup to verify that OS-9 allocates memory using first-fit rules.

```
$ Sleep 600 #340k&
```

The memory for this ***sleep*** could fit in any of the four large blocks of free memory (see figure 4.4). If OS-9 is using best-fit, it will land in the 354.25 kilobyte slot. If it is using first-fit, it will land in the 463 kilobyte slot or the 436.25 kilobyte slot depending on the direction from which it is searching. Using a worst-fit algorithm, OS-9 would pick the 484.25 kilobyte slot. Another ***mfree*** command gives the output in figure 4.5. This tells us that OS-9 used the memory from $17700 to $6d7ff for the memory needed by ***sleep***, and demonstrates that OS-9 uses first-fit allocation.

4.3 Memory Fragmentation

Every method of allocating system memory on the fly can be pushed into a situation where there is plenty of memory available, but the memory is divided into so many

Figure 4.3: Displays while ***Sleep*** s are Active

```
Minimum allocation size:       0.25 K-bytes
Current total free RAM:      435.25 K-bytes

Free memory map:

    Segment Address        Size of Segment
   -----------------   --------------------------
       $15700          $200             0.50 K-bytes
       $16700          $B00             2.75 K-bytes
       $170000         $6AB00         426.75 K-bytes
       $1E6D00         $800             2.00 K-bytes
       $1EF100         $400             1.00 K-bytes
       $1F0000         $500             1.25 K-bytes
       $1F4E00         $100             0.25 K-bytes
       $1F5400         $100             0.25 K-bytes
       $1F6400         $100             0.25 K-bytes
       $1FC700         $100             0.25 K-bytes
```

small blocks that it is useless. If it were possible to shift the allocated blocks of memory around until all the free space between them was squeezed out to one end, fragmented memory could be made useful again. The process of rearranging memory to make large blocks of free space is called "garbage collection." Basic and lisp usually have built in garbage collection—they pause from time to time and organize their storage. OS-9 doesn't do garbage collection, but if you usually run just one or two processes at a time you probably won't have any trouble with memory fragmentation.

Memory fragmentation is caused by dynamic memory demands. When OS-9 only has to deal with one or two blocks of memory at a time, it can keep things in good order. If you allocate and release large blocks of memory frequently, there is lots of potential for trouble.

One cause of fragmentation is hard to control. The first time a device is opened OS-9 allocates static memory for it out of system memory (high memory). If high memory is crowded when you open the device, the static storage could be located in an inconvenient spot. Killing processes and unlinking modules won't make the static storage go away. The best way to avoid the problem is to open your devices early even if you don't plan to use them until later. An ***iniz*** command in the startup file is the best way to get all the devices initialized early.

```
$ iniz t1 t2 d0 d1 h1 r0
```

Figure 4.4: Some *Sleep* s Done

```
Minimum allocation size:        0.25 K-bytes
Current total free RAM:      1761.50 K-bytes

Free memory map:

    Segment Address         Size of Segment
   -----------------   -------------------------
       $15700          $200            0.50 K-bytes
       $17700          $73C00        463.00 K-bytes
       $91400          $58900        354.25 K-bytes
       $EFE00          $79100        484.25 K-bytes
       $16F000         $6D100        436.25 K-bytes
       $1DDF00         $1600           5.50 K-bytes
       $1E0B00         $1E00           7.50 K-bytes
       $1E3100         $800            2.00 K-bytes
       $1E6D00         $1000           4.00 K-bytes
       $1EF100         $400            1.00 K-bytes
       $1EF700         $800            2.00 K-bytes
       $1F4E00         $100            0.25 K-bytes
       $1F5300         $200            0.50 K-bytes
       $1F6400         $100            0.25 K-bytes
       $1FC700         $100            0.25 K-bytes
```

In the previous example, the fragmentation took place in data storage, but module storage can have the same trouble. If you use modules heavily—loading them when you need them and unlinking them when you don't—you can fragment memory.

Starting lots of processes (as we did with *sleep*) exercises OS-9's memory-allocation system. Each process allocates some data space. If all processes retain their memory for about the same length of time, any fragmentation tends to heal eventually…at least it seems under control. The worst situation is caused by a long-running process that has a chunk of memory right in the middle.

There is only one way to de-fragment memory: kill some processes so they release their memory. Then restart them. The restarted processes will get memory at the far ends of memory and leave the prime locations in the middle free. In the previous example, the fragmentation situation would have been much improved if we had killed the second 20k sleep, process eight. If we had killed all of the sleeps with 20k of memory, free memory would have been nearly contiguous.

Figure 4.5: Test for First-Fit Allocation

```
Minimum allocation size:       0.25 K-bytes
Total RAM at startup:       2044.00 K-bytes
Current total free RAM:     1409.75 K-bytes

Free memory map:

    Segment Address        Size of Segment
   -----------------   --------------------------
       $15700          $200            0.50 K-bytes
       $6D800          $1DB00        118.75 K-bytes
       $91400          $58900        354.25 K-bytes
       $EFE00          $79100        484.25 K-bytes
       $16F000         $6D100        436.25 K-bytes
       $1DDF00         $1600           5.50 K-bytes
       $1E0B00         $800            2.00 K-bytes
       $1E3100         $800            2.00 K-bytes
       $1E6D00         $1000           4.00 K-bytes
       $1EF100         $400            1.00 K-bytes
       $1F4E00         $100            0.25 K-bytes
       $1F5300         $200            0.50 K-bytes
       $1F6400         $100            0.25 K-bytes
       $1FC700         $100            0.25 K-bytes
```

4.4 Memory Protection

Systems with memory protection hardware (an MMU[3]) can use OS-9 SSM support. This addition to the OS-9 kernel implements several protection boundaries.

- The kernel and other system code have unlimited access to memory.
- User-state processes have unlimited access to their data area and any memory they acquire with the `F$SRqMem` SVC. They also have access to modules that they find with the `F$Load` or `F$Link` SVCs. The main program module is linked for the process by the `F$Fork` that started it. Access to modules may be limited by the access permissions in the module header.
- A process has access to all the memory of processes that it spawns with the `F$DFork` call.

[3] Microware supports several memory management units: the 68020 with the 68851 coprocessor, the 68030, the 68040, the 68451, and the P32. Other MMUs require new SSM modules.

The limitations of the MMU constrain the values used for D_BlkSiz, the units of memory OS-9's memory management subsystem uses for allocation. Four kilobyte units of memory are common in systems with SSM because that block size is compatible with the MMU hardware Microware supports.

4.5 Memory Management Service Requests

There are only four system service requests that directly affect memory management: FMem, FSRqMem, F$SRqCMem, and F$SRtMem. These requests set the memory allocation of a process. The memory management SVCs control the allocation of two classes of memory: program data memory and system memory.

The program data area is for predictable memory requirements such as a program's stack and static memory requirements. Each process is given one block of program data area when it is forked. The size may be decreased as the process runs, but a process can never have more than one data area.

System memory is for temporary or unpredictable memory requirements. A process can have many blocks of system memory, but the blocks can't be resized. Processes start with no system memory, but can request (and return) blocks of it as they run.

Program data area memory is located as near to the bottom of memory as possible, and system memory is located high in memory. The different types of memory are allocated from areas that are as far apart as possible to work against fragmentation. It is particularly important to keep the operating system's tables (which tend to be small and long-lived) away from the process stacks (which tend to be large and short-lived). If system data structures were allocated from the same end of memory as process stacks, path buffers and similar system memory would quickly fragment memory by appearing directly above each stack allocation.

The F$Mem SVC controls the size of the program data area. When F$Mem is called, the D0 register must contain the number of bytes you would like the process to have in its data memory area. If the amount of memory requested is less than the current memory size, but not zero, OS-9 decreases the allocation to the amount requested and returns the new amount of memory in D0 and upper bound of the region in A1. If additional memory is required, OS-9 returns an E$NORAM error.[4] The actual size allocated is useful because OS-9 always allocates memory in pages of D_BlkSiz bytes. Your request will be rounded up to the nearest page. If the amount of

[4] OS-9 lost the ability to expand the stack with F$Mem when it gained colored memory. There is some sense to this new behavior. On OS-9/6809 Level Two the address translation hardware and software would let F$Mem succeed if there was free memory anywhere in the system. Without address translation, the chances of F$Mem finding free memory above the current data area are pretty good but not certain. The kernel implementors opted for speed, small size, and a reliable response even if the response is always no.

memory requested is zero, OS-9 doesn't change the memory allocation. It only returns the size and high bound of the process' memory.

The F$Mem request has several possibilities for error. First, successful expansion is so unreliable that the kernel doesn't even try. Expansion requires free memory immediately above the current data memory. In a quiet system that might work, but if other processes are active, their data areas may be located directly in the expansion path. Even decreasing the memory allocation can cause trouble. If you try to release memory including the page containing the top of the stack (where the stack pointer, A7, is pointing), OS-9 will accuse you of a suicide attempt and return an error.

The data memory area is a contiguous block of memory that always contains the stack and the process' parameter area. Programming languages usually keep all variables in this area. The stack grows from the top of the data memory area down. Static variables are allocated from the bottom up. The following fragment of C code demonstrates this.

```
int array1[50];                 /* Stored near the bottom of data memory      */
char *string="Test string";     /* The pointer, string, is near the           */
                                /* bottom of data memory. The string          */
                                /* itself is kept in the program module.      */
main()
{
    int test1;                  /* These are automatic variables. They are    */
    int test2;                  /* stored on the stack.                       */
    static int test3;           /* This one's static. It is allocated         */
                                /* near the bottom of the data area.          */
    ...
}
```

The linker sets the size of the data area by adding up the stack-space and static data requirements of all the psects making up a program. You can increase this number with a linker option, or use the shell's "#" option to increase it when the program is started.

When a program needs memory in unpredictable amounts, it should use dynamic allocation. In C, the malloc() function is the usual way to dynamically allocate memory. Pascal programmers use NEW. These functions use the OS-9 F$SRqMem SVC to get blocks of memory from the system memory area. Once a block of memory is allocated by F$SRqMem its size is fixed, but a program can allocate any number of non-contiguous blocks of system memory. Each request for system memory is filled by a simple first-fit search of free memory. Programs routinely allocate and free system memory as they run.

The simple F$SRqMem system call is equivalent to the colored-memory system call F$SRqCMem with a memory type of 0. If a type other than zero is specified, the F$SrqCMem is constrained to return only the type of memory requested—or E$NoRAM.

System memory can be returned to the system one block at a time. The F$SRtMem SVC takes the address and size of the block of system memory and returns it to the pool of free memory. Even if a process fails to explicitly free memory that was allocated to it, OS-9 frees the memory when the process terminates.

Memory allocated to system code like device drivers, system-state processes, and SVC's is not automatically freed by the kernel. System state code that allocates memory *must* free the memory or it will remain allocated until the system is rebooted.

Chapter 5

Memory Management Internals

This chapter details some of the algorithms and data structures that the OS-9 kernel uses for memory management.

5.1 The Process Memory List

To insure that all memory allocated to a process is freed when that process exits, the kernel must keep track of the memory allocated to each user-state process. The process descriptor contains the location and size of the process' stack allocation and points to a linked list containing the locations and sizes of the the other blocks of memory allocated to the process. Whenever the kernel allocates memory to a process via the F$SRqMem system call, it records the address and length of the memory block in the process' memory allocation list. In very early versions of OS-9 the list was a 32-entry table. This literally meant that each process was allowed to do only a fixed number of F$SRqMem calls without freeing a block with F$SRtMem. Later, the kernel attempted to merge each memory allocation with an adjacent entry in the allocation table. In practice, this meant that processes could usually allocate far more than 32 blocks. Starting at release 3.0 the table has been converted to a list. This makes memory allocation faster and removes one reason for failure in F$SRqMem, but it also hurts the performance of F$SRtMem which has to search an arbitrary-length list for the memory that is being returned.

Although a process will not overflow the allocation list, it is still best to keep the list short. If the process is a C program that attempts to use the ibrk() function before it falls back on ebrk() or _srqmem() for memory allocation, it might be worth starting with a larger memory allocation, but increasing the size of malloc()'s minimum memory request with _mallocmin() is a more reliable technique.

Adding a call to _mallocmin( ) near the beginning of a C program—right after the declarations in main( )—is the simplest and most effective way to minimize the length of the process memory allocation list. The default minimum F$SRqMem size for the malloc family is the greater of 512 bytes or the value of D_BlkSiz from system globals.

For example, a program that allocates 124 kilobytes in little chunks could be improved by adding:

```
    _mallocmin(124*1024);
```

to the beginning of main( ). This new minimum allocation value keeps the allocation list short. It also (sometimes quite importantly) usually prevents malloc( ) from making a system call: a potential major performance improvement.

Changing the value of M$Mem or M$Stack to prevent fragmentation only rarely works, but it is easy and the technique can be used on modules for which the source code is not available. (Although changing M$Mem is not a reliable fix for process memory list overflows, changing M$Stack is very effective at curing stack overflows.) Before trying this approach, it is prudent to experiment by running the program with the process' initial memory allocation temporarily changed by the shell's # command line option. The process executed by:

```
    $ test #100k
```

forks the program with 100 kilobytes more than its default allocation.

The default memory allocation for a module can be changed in the linker:

```
    $ l68 –M=24k test.r
```

or in the C compiler executive:

```
    $ cc –olM=24k test.c
```

For modules that only exist in compiled and linked form, the default memory allocation can be changed with ***moded***. ***Moded*** can edit the defined fields in any type of module, provided that the module type is described in the moded.fields file. The moded.fields file does not usually include a description for the format of program modules. This is easy to fix.

Moded.fields is usually found in the SYS directory. If it does not include a line that starts:

```
#1,0
```

add the following text to the end of moded.fields:

```
*========  Program Module ============
#1,0
Module owner’s group
2,8,10,0
!This is the number of the group that owns the module.
!The owner field is used in conjunction with the module
!protection attributes
Module owner’s userid
2,a,10,0
!This is the number of the user that owns the module.
!The owner field is used in conjunction with the module
! protection attributes
Module name
5,c,0,0
!The name of the module
Module access permissions
2,10,16,0
!reserved (4 bits)
!public   (4 bits)
!group    (4 bits)
!owner    (4 bits)
!  Within a 4-bit set
!   bit 3 reserved
!   bit 2 execute
!   bit 1 write
!   bit 0 read
!   -----ewr-ewr-ewr
Module revision
1,15,10,0
!Module revision is used to govern replacement of modules
!already in the module directory.
Module edition number
2,16,10,0
!The module edition number is just a comment
Memory size
4,38,10,0
!The required size of the module’s data area
Stack size
4,3c,10,0
!The required size of the module’s stack area
```

This description of a program module includes the most important fields in the program module header. Using it, ***moded*** can update the memory allocation of a module. The following script shows how to change the stack memory allocation for ***build*** from 3100 bytes to 4000 bytes:

```
2.$ moded build
    OS-9/68000 Module Editor
    Copyright 1987 Microware Systems Corp.
    Type ?  for editing help message

moded:  e
Module owner's group          :        1 =
Module owner's userid         :        0 =
Module name                   :    build =
Module access permissions     :    $0555 =
Module revision               :        2 =
Module edition number         :       18 =
Memory size                   :     1800 =
Stack size                    :     3100 = 4000
moded:  w
moded:  q
2.$
```

For OS-9 versions 2.4 and 3.0, the memory allocation for program modules is the sum of the stack size and memory size from the module header, plus the size of parameters passed when the program is forked, plus any additional memory requested when the program is forked. The field is used by F$Fork and F$Chain to help setup initialized data. Consequently, it is usually best to preserve the value of M$Mem and use M$Stack's value to modify the initial memory requirement of a module.

5.2 Fragment Lists

SSM makes fragment lists necessary, but they are useful even when there is no memory protection hardware. They give excellent performance in one common special case, prevent performance from going completely bad in another common special case, and help prevent fragmentation.

Fragment lists form buffers between the kernel's main list of free memory and each process. The value of D_BlkSiz in system globals controls the minimum size of allocations from the system memory list; D_BlkSiz is generally set around 256.[1] D_MinBlk, in system globals, controls the minimum block size of memory allocated to processes; D_MinBlk is almost invariably set to 16 bytes.[2] Allocations from the system free memory list are rounded up to a multiple of D_BlkSiz bytes, and the amount of memory returned to the caller is rounded up to a multiple of D_MinBlk.

[1] 4096 for most systems with SSM.

[2] D_MinBlk must be set to a power of two, and since some processors only load full words (such as pointers) from full word boundaries, D_MinBlk must be at least 4 bytes. Sixteen-byte blocks of memory keep allocated memory aligned enough to make even the 68040 happy.

When D_BlkSiz is not equal to D_MinBlk there may be a difference between the amount of memory taken from the system free memory list and the amount delivered to the caller. This extra memory is left in a fragment list.

Imagine a program that uses F$SRqMem calls to allocate memory for linked list nodes and F$SRtMem calls to release the memory from nodes that are not in use. Pseudo-code for the insert and delete functions would look like this:

```
Insert(data, after)
datatype data
nodetype after                                    Insert after this node
{
    newnode = F$SRqMem(nodesize)
    newnode→data = data
    newnode→next = after→next
    after→next = newnode
}

delete(after)
nodetype after                                    Delete the node after this one
{
    holdptr = after→next
    after→next = after→next→next
    F$SRtMem(holdptr)
}
```

If the kernel did not use fragment lists, these functions would run very slowly and very likely cause such horrible fragmentation that no other process could allocate memory. With fragment lists in operation, these functions will not cause horrible fragmentation and their performance will be much better than they would be without fragment lists.

Without fragment lists, the best we could hope for would be for all the nodes to be allocated from contiguous memory. Then ten-thousand 64-byte nodes would use a bit more than half a megabyte and as further insertions and deletions took place, around ten-thousand nodes would continue to use around a half megabyte. If other processes had already fragmented memory somewhat, insertions would fill 32 empty spaces in memory. Then the process' memory list would fill and it would be unable to allocate more memory. The memory it had allocated would cause fragmentation until the process exited or freed the memory some other way.

With the fragment list, memory is drawn from the system list 256 bytes at a time. A F$SRqMem for 64 bytes gets 256 bytes from the system memory list, leaves 192 bytes in the process' fragment list and returns 64 bytes to the process. The next three F$SRqMem system calls are satisfied from the fragment list. F$SRtMem system calls for 64-byte chunks of memory are also caught in the fragment list. There the memory is used to satisfy further `F$SRqMem` calls until they can be coalesced with other fragments into a 256-byte block that can be returned to the system memory list. After an initial allocation phase, the process will probably do almost all its memory operations in and out of its fragment list.

Since memory in the fragment list is already allocated to the process:

- Operations on the fragment list do not have to call the SSM functions to change memory's protection attributes.
- The process memory list does not need to be updated.
- Only the performance of the process owning the fragment list is hurt by the length of the free list caused by the tiny fragments.
- Since any contiguous block of D_BlkSiz or more bytes is returned to the system memory list, even the process owning the fragment list need not attempt to return freed memory to the fragment list when it frees more than D$BlkSiz bytes. This improves performance for all processes.
- When the process uses chiefly blocks of some particular small size (64-bytes here), the fragment list serves as a cache for those memory blocks. `F$SRqMem` system calls are almost always satisfied from the first node in the fragment list.

Fragment lists prevent process' memory allocation list from growing as fast as they might, and sometimes improve performance. However, in a system without an MMU, the use of fragment lists removes memory from the general system pool and commits it to a process before the process requests the memory. For instance, with D_BlkSiz of 256 bytes and D_MinBlk of 16 bytes, a request for 32 bytes returns 32 bytes to the calling process and leaves $256 - 32 = 224$ bytes in the process' fragment list. If the process never requests another block of memory less than or equal to 224 bytes in size, that memory goes unused. If D_BlkSiz had been 16 bytes, no memory would have gone to the fragment list and those 224 bytes would have been available to other processes.

Since fragment lists add an additional layer to the memory allocation and deallocation algorithms, it complicates the algorithms. This makes the worst-case performance of the memory allocator better when the fragment list is disabled.

5.3 Colored Memory

All memory is not the same. Even a simple system usually contains RAM and ROM. More complicated systems have non-volatile RAM, fast RAM, slow RAM, video RAM, RAM that is available for DMA, and perhaps other classes of memory as well. The

Figure 5.1: Colored Memory List Entry Format

Type	Priority	Access	Block size
Low boundary		High boundary	
Description		Translation address	
Reserved		Reserved	

OS-9 colored memory structure lets the kernel recognize these distinctions and lets programs request specific types of memory when they have special requirements.

Colored memory might have been called typed memory or classified memory, but color is a nice attribute with hints of particle physics and graph theory. Any description that might actually make sense when applied to memory might constrain people's thinking about memory allocation. Nobody cares about the actual color of memory (if color applies at all), so we can use the adjective to mean whatever we like.

During initialization, the bootstrap code looks for a colored memory definition list in the init module. If it finds a colored memory list, it amends its built-in list of memory ranges using the colored memory list. This list itemizes each address range that might contain memory, and the attributes of memory that might be found in that address range. The initialization code inserts each block of RAM into the system's list of free memory with the attributes given to that range of memory in the init module. Blocks of ROM identified by the colored memory definition are added to the list of ROM used by the boot code and are searched for memory at boot time.

Some of the information in the colored memory definition list is entirely for the convenience of the kernel:

The range of local bus addresses for this memory This is the high and low address the kernel should use when looking for this memory.

The granularity of the boot-time search for memory in this address range When the kernel is checking to see where memory exists in the address range, it probes for memory then skips ahead this many bytes. If the number is too small, booting will be slow. If the number is too large, the bootstrap might skip over some memory or fail to accurately find the end of a block of memory.

The external bus translation address On a multi-master system with dual-ported RAM this is the address of the beginning of the block when seen from another bus master's point of view. This value is used by the `F$Trans` SVC, which is mainly used by drivers and multi-CPU communication packages.

The other fields in the colored memory definition list directly affect the way memory is allocated.

- The memory type attribute is used when a system call requests a particular type of memory. The `F$SRqCMem`, `F$DatMod`, and `F$Load` system calls all take a memory type parameter. If the type is zero, the kernel ignores type when finding memory to satisfy this request. If the type is not zero, the kernel only considers memory of the requested type.
- The memory priority attribute is used for every system call that allocates memory. If the call does not specify a type, the call returns the highest priority memory that it can find. If the call does specify a type, the search is performed in descending priority order constrained to colors of that type.
- The access permissions of the memory:

  B_USER Bit 0: This memory is available to user processes. In OS-9 release 2.4.3, the B_USER bit affects the memories *visibility* but does not affect its usability. B_USER should always be set for memory that should be available to user code. Future releases of OS-9 may (in my view, *should*) fully support the B_USER attribute such that only memory requests from system code can allocate memory without the B_USER attribute.

  B_PARITY Bit 1: The system initializes the parity in this range of memory at boot time. If parity checked memory is read before it is written for the first time, it has an even chance of returning a parity error; consequently, the boot code writes all parity checked memory as part of the bootstrap process.

  B_ROM Bit 2: This attribute is called ROM, but it should not be taken too literally. Memory with this attribute is searched for modules at boot time. Setting this attribute for non-volatile RAM, or even ordinary RAM when the power is not turned off before the boot, causes the bootstrap to find any modules left in the RAM and register them in the module directory. Nevertheless, it is usually a bad thing to turn on the B_ROM attribute for memory that is not actually ROM. Parity checked RAM that is given the B_ROM attribute is not initialized—and consequently may have random parity after system initialization—even if it has the B_PARITY attribute. Memory with the B_ROM attribute is not included in the system free memory list, so it cannot be allocated by the kernel.

  B_NVRAM Bit 3: Like ROM, this memory is searched for modules at boot time. Unlike ROM, memory in this class that is not used for modules is included in the system free list.

Although the name says non-volatile RAM, ordinary RAM can be called NVRAM. Of course, calling it non-volatile won't let it survive a power failure, but modules in ordinary RAM will be found after a reset if the memory is in the NVRAM class. This can save lots of time during debugging. Calling RAM NVRAM during the debugging cycle is often a good idea, but it has a subtle pitfall. Every module in NVRAM will be included in the module directory after the sytem is booted unless it has a bad CRC. If you are debugging a system module of some sort—a kernel extension module, driver, file manager, or even a shell—it is good to give the module a bad CRC value before you reset or early in the boot cycle. It is disconcerting to find a bug in a kernel extension module, reset, boot from a disk without the buggy module module, and find the defective module still part of the system.

B_SHARE Bit 4: This name is a sign of work in progress, not a completely supported feature.

OS-9 does not support memory shared between processors, but this is the first step. The kernel's memory allocator places its control structures for shared memory in the the same block of shared memory. If the kernel ever supports multiple processors this will let multiple processors allocate memory from the shared types.

Memory with a priority of zero is a useful special case. It can only be allocated by a system call that specifically requests memory of that type.

When the kernel can satisfy a memory request from two areas with the same priority, it allocates the memory from the area with the most free memory.

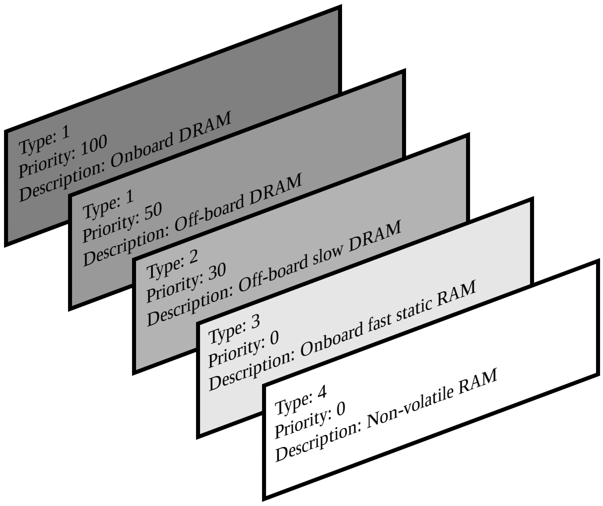
5.3.1 Colored Memory and Fragment Lists

Memory retains its color information even after it has been moved from the system's main free memory list to a fragment list. Each process descriptor has pointers to a doubly-linked colored memory descriptor list that contains descriptors for every memory color that has ever been in that process' fragment list.

The following describes the colored memory data structures (see figure 5.3 for a picture).

- The memory list in the init module is used to build the kernel's master colored memory descriptor list. The colored memory descriptor list is a doubly-linked list of descriptors that contain information about the color, and pointers to the free memory list and system fragment list for that color.

Figure 5.2: Example of a System with Colored Memory


Type: 1
Priority: 100
Description: Onboard DRAM
Type: 1
Priority: 50
Description: Off-board DRAM
Type: 2
Priority: 30
Description: Off-board slow DRAM
Type: 3
Priority: 0
Description: Onboard fast static RAM
Type: 4
Priority: 0
Description: Non-volatile RAM

- The system fragment lists (one per color) are used for memory allocation services requested by operating system code.

- The free memory lists (one per color) are used for all memory allocation services that are not completed at the appropriate fragment list.

- Each process descriptor contains pointers, _cfrag[0] and _cfrag[1], that link it to a doubly-linked list of colored memory descriptors: one descriptor for each memory color that has ever been in that process' fragment list.

- The process colored memory descriptor lists use the same structures as the system colored memory descriptor lists, but they only have fragment lists attached to them; there are no process-specific free memory lists.

5.3.2 Case Studies

Case One

A system has fast memory and slow memory and we want to configure it to use the slow memory only when it runs out of fast memory. We give the fast memory a higher priority than the slow memory:

```
MemList
*       MemType  type,priority,attributes,blksiz,low-limit,high-limit,
*                name,DMA-offset
        MemType  SYSRAM,136,B_USER,4096,0,$200000,Fast,0
        MemType  SYSRAM,120,B_USER,4096,$400000,$800000,Slow,0
        dc.l     0        end of list
Slow    dc.b     "Slow RAM",0
Fast    dc.b     "Fast RAM",0
```

With this memory list, all memory requests that can be satisfied from the memory with a priority of 136 use that block of memory. Other requests fall back on the memory with a priority of 120.

Case Two

A system has fast memory and slow memory and we want to configure it so the fast memory is hard to get. One approach is to make the fast memory available for all callers, but insist that they ask for it:

```
FSTRAM  equu     0x02
MemList
*       MemType  type,priority,attributes,blksiz,low-limit,high-limit,
*                name,DMA-offset
        MemType  SYSRAM,128,B_USER,4096,$400000,$8000000,Slow,0
        MemType  FSTRAM,0,B_USER,4096,0,$200000,Fast,0
        dc.l     0        end of list
Slow    dc.b     "Slow RAM",0
Fast    dc.b     "Fast RAM",0
```

This use of priority zero memory forces callers to *ask* for fast memory. The kernel returns E$NoRAM to a caller rather than giving fast RAM to a process that asked for ordinary RAM.

Case Three

Combining type and priority lets the system hand out fast or slow RAM preferentially but still allow callers to request the type they want. Here's the memory list that allocates slow memory first when the caller doesn't specify a type:

```
FSTRAM  equ      0x02
MemList
*       MemType  type,priority,attributes,blksiz,low-limit,high-limit,
*                name,DMA-offset
        MemType  SYSRAM,136,B_USER,4096,$400000,$800000,Slow,0
        MemType  FSTRAM,120,B_USER,4096,0,$200000,Fast,0
        dc.l     0        end of list
```

```
Slow     dc.b     "Slow RAM",0
Fast     dc.b     "Fast RAM",0
```

Case Four

A system has three types of RAM:

- 512 kilobytes of memory that can be used by video processor A,
- 512 kilobytes of memory that can be used by video processor B, and
- 1024 kilobytes of memory that neither video processor can reach.

Since data for the video processors tends to use large amounts of memory, we want to preserve the video memory for images when possible. When no other memory is available, the kernel should allocate memory from the banks of memory accessible to the video processors. Programs call for memory that is accessible to one video processor or the other, but they generally ask for system memory without specifying a type. The memory list for such a system might look like:

```
MemList
*        MemType  type,priority,attributes,blksiz,low-limit,high-limit,
*                 name,DMA-offset
         MemType  SYSRAM,136,B_USER,4096,$100000,$200000,SysMem,0
         MemType  VIDEO1,120,B_USER,4096,0,$80000,Plane1,0
         MemType  VIDEO2,120,B_USER,4096,$80000,$100000,Plane2,0
         dc.l     0        end of list
SysMem   dc.b     "System memory",0
Plane1   dc.b     "Video Plane A memory",0
Plane2   dc.b     "Video Plane B memory",0
```

Since the two video planes have the same priority, the kernel satisfies requests that don't specify a memory type from the SYSRAM type, then, if there is insufficient RAM there, the request goes to the video plane with the most free memory. This keeps the memory load roughly evenly divided between the image planes.

Case Five

Memory requests must be satisfied from one color of memory. This restriction can be used to create artificial barriers. This is generally a silly idea, but it could be useful in special cases. For instance, even a system with only one type of memory can use colored memory to set aside a block of memory for a special purpose:

```
MemList
RESRAM   equ      2
*        MemType  type,priority,attributes,blksiz,low-limit,high-limit,
*                 name,DMA-offset
         MemType  SYSRAM,128,B_USER,4096,0,$180000,SysRam,0
         MemType  RESRAM,0,B_USER,4096,$180000,$200000,Reserved,0
         dc.l     0        end of list
SysRam   dc.b     "System memory",0
Reserved dc.b     "Reserved memory",0
```

There might also be some reason to reject requests for large quantities of memory:

```
MemList
*        MemType  type,priority,attributes,blksiz,low-limit,high-limit,
*                 name,DMA-offset
         MemType  SYSRAM,128,B_USER,4096,0,$200000,SysRam,0
         MemType  SYSRAM,128,B_USER,4096,$200000,$400000,OSRam,0
         dc.l     0        end of list
SysRam   dc.b     "System memory",0
OSRam    dc.b     "Reserved for OS",0
```

Even though these colors of memory have identical characteristics except for their address ranges, they are recognized as distinct colors and every memory request will be satisfied from the color with the most free memory.[3] A system with this memory list will be unable to fill a request for more than two megabytes of memory even if more than that is free.

Case Six

In some circumstances a memory list like the one shown above will control fragmentation, but colored memory offers potential for a better solution.

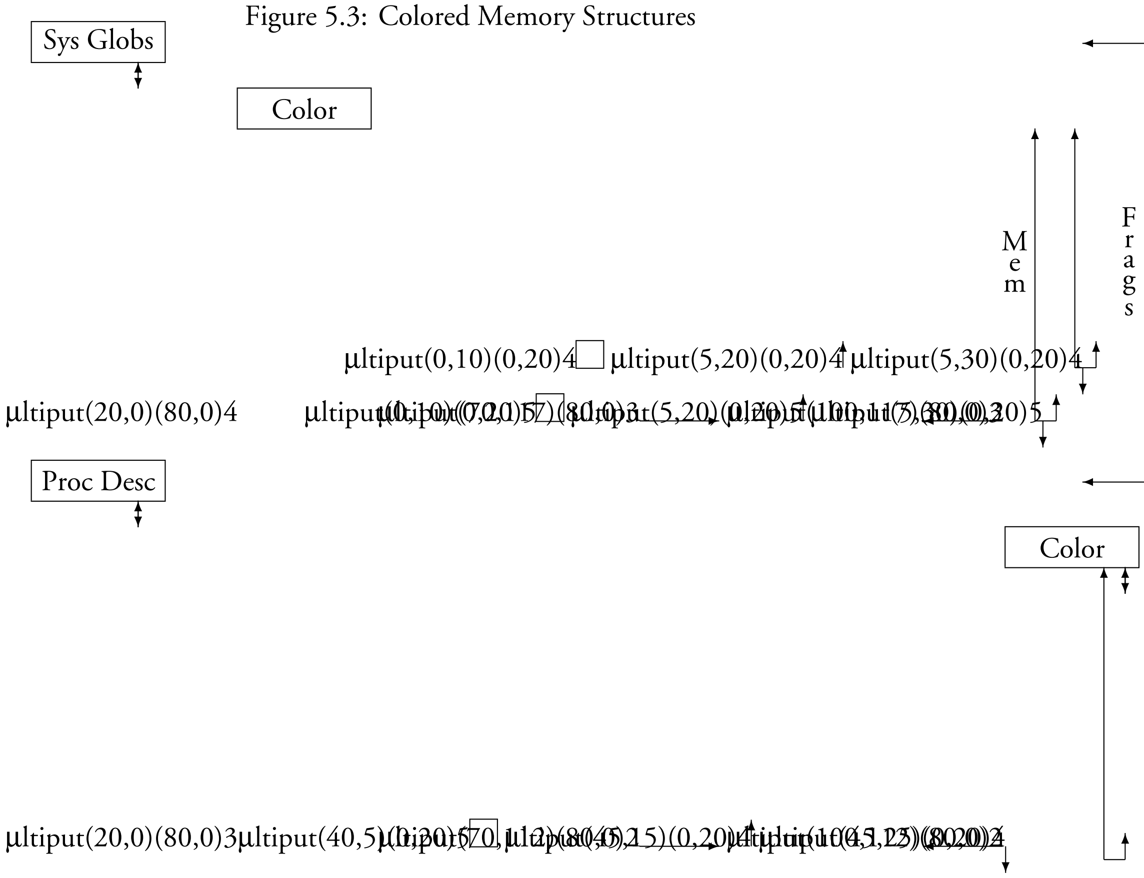
In OS-9 release 3.0, the following trick does not work, but it will be useful if Microware fully implements the B_USER attribute.

```
MemList
*        MemType  type,priority,attributes,blksiz,low-limit,high-limit,
*                 name,DMA-offset
         MemType  SYSRAM,128,B_USER,4096,0,$380000,SysRam,0
         MemType  SYSRAM,136,0,4096,$380000,$400000,SysRam,0
         dc.l     0        end of list
SysRam   dc.b     "System memory",0
```

[3] Though the other color will be tried if the first returns E$NoRAM. It is possible for the color with the most memory to be too fragmented to satisfy a request, while the color with less free memory could have a larger block of contiguous free memory.

Memory allocated by the kernel uses high RAM until it overflows. This prevents I/O buffers and other system data structures from appearing in the middle of memory. If the kernel expands the event table (or any other system data structure) and the memory allocator gives it memory in the middle of the main range of RAM, only a reboot or a sufficient increase in the number of events to call for another event table expansion will free that memory. Preventing that situation may be worth the small memory waste imposed by a reserved region for operating system memory.

Figure 5.3: Colored Memory Structures



Chapter 6

The Buddy System Allocator

Starting at OS-9 release 3.0 the OS-9 kernel can be configured with either the standard allocator or a buddy system allocator. The buddy system allocator is less flexible than the normal allocator, but its worst-case performance is attractive.

6.1 Overview

The buddy system memory allocator is designed for real-time applications that must include memory allocation/deallocation in real-time sections of their code. The performance of the buddy system allocator is about the same as the standard allocator. The features and system interfaces of the two allocators are close enough that almost every system can use either allocator without change. You could probably use a kernel with the wrong allocator and not notice the difference for weeks.

The standard allocator is preferable for most applications. The kernel code for the standard allocator has been "burnt in" for years this lends it a presumption of correctness. Although the buddy system allocator is is much simpler than the standard allocator[1] it should be viewed slightly skeptically for a while. At release 3.1 it can probably be considered "mature code."

The buddy allocator might be useful for its strict alignment characteristics, but it is essential for programs that must use memory allocation services in real-time code. When possible, programs should avoid memory allocation or deallocation in real-time code. System calls that use the memory allocator are not tuned for real-time

[1] I cannot find any defect in the buddy system allocator. In fact, its simplicity should make it more reliable than the standard allocator. I suggest caution simply because my experience with system software is that bugs are more common in new code.

performance. They mask interrupts too long and are about half as fast as most SVCs. When memory must be allocated during critical real-time intervals the buddy system is preferable. Although its performance is roughly the same as the standard allocator's typical performance, the buddy allocator's performance is stable under all circumstances and the standard allocator is only stable under all reasonable circumstances.

The crucial advantage of the buddy system allocator is that its worst-case execution time depends on the logarithm of the size of memory. The worst-case execution time of the standard allocator depends linearly on the size of memory. Theoretically, if the standard allocator needs about 100 microseconds to allocate memory in a typical system, it could use more than one-hundred seconds in a hideously fragmented system with four gigabytes of RAM.

A suitably fragmented system could be created like this:

```
do{
    size = 2*D_MinBlk;
    if((errno = _os9_srqmem(&size, &ptr)) == SUCCESS)
        _os_srtmem(size/2, ptr);
}while(errno == SUCCESS);
```

With D_MinBlk of 32 and four gigabytes of free memory, the loop will execute 67,108,863 times and leave 67,108,863 fragments. If the allocator needs 2 microseconds to check each fragment in a first-fit search for 64 bytes, it will use 134 seconds to fail on the last _os_srqmem( ).

The buddy system allocator doesn't suffer from anything like fragmentation. For it, the worst case is the first allocation of a small block in a system that has only big blocks of RAM. In a system with four gigabytes of RAM and a processor similar to the one used to demonstrate the first-fit allocator, a single memory allocation might go as high as 150 microseconds.

In practice, a system using the standard allocator rarely has more than about 20 memory segments, regardless of the size of its memory. In this case the standard allocator and the buddy allocator have very similar performance.

The buddy allocator has three important restrictions.

1. It can only allocate memory in power-of-two size blocks.

2. It can only allocate an *n*-byte block of memory on an *n*-byte boundary.

3. It can only free the exact blocks of memory it allocates. It is not possible to free two contiguous blocks of memory with one F$SRtMem system call or return part of an allocated block of memory to the system.

   If a program asks for 128k of memory and discovers later than it only requires 64k, it cannot simply return the surplus. The only way to release unused memory is to return the entire block and get a new allocation of the correct size.

6.2 The Buddy System Algorithm

The buddy allocator maintains an array of free memory segment lists, one for each supported size: 16 bytes, 32 bytes, 64 bytes…, 2 megabytes, 4 megabytes, 8 megabytes, and so forth. If a memory request can be filled with an existing segment, the allocator removes the first segment from that free list. Memory requests that succeed at this stage take a small, constant amount of time.

If there is no entry in the free list for the requested size, the allocator gets a segment from the next larger size, returns half of the segment to the caller and places the other half (the buddy) in the free list. This adds a small amount of time to the system call.

If the free list for the next larger size is also empty, the buddy allocator continues checking larger sizes until it finds free memory. When it finds memory, it carries it back level by level, leaving a buddy at each level it passes until it reaches the list for the requested memory size. There it leaves the last buddy and gives the remainder to the caller.

The time required to search up the array of free lists and step back down the list dropping off buddies depends on the number of lists it has to visit before it finds some free memory. This cannot be more than the number of valid memory sizes. If the minimum memory allocation size is sixteen bytes and the maximum size is four gigabytes, there are $32 - \log_2(16) = 28$ valid allocation sizes.

If a process were to request 250 bytes of memory in a system that had no free segments smaller than 1024-bytes, the allocator might follow these steps:

- Round 250 up to the next higher power of two, 256.
- Check the list of 256-byte segments. It is empty.
- Check the list of 512-byte segments. It is also empty.
- Check the list of 1024-byte segments. There is a free 1024-byte segment.
- Remove a 1024-byte segment from its free list.
- Place 512 bytes of the 1024-byte segment in the 512-byte free list.
- Of the other 512-byte half, place half in the 256-byte free list.
- Return the remaining 256 bytes to the caller.

The allocator had to check three free lists in its search for free memory, and modify each of those free lists on its return.

Figure 6.1: Example of Buddy System Working

1 F$SRqMem for 250 bytes

2 Rounded to 256 bytes

3 Check 256-byte free list

4 Check 512-byte free list

5 Check 1024-byte free list

6 Found memory

7 Remove a free block

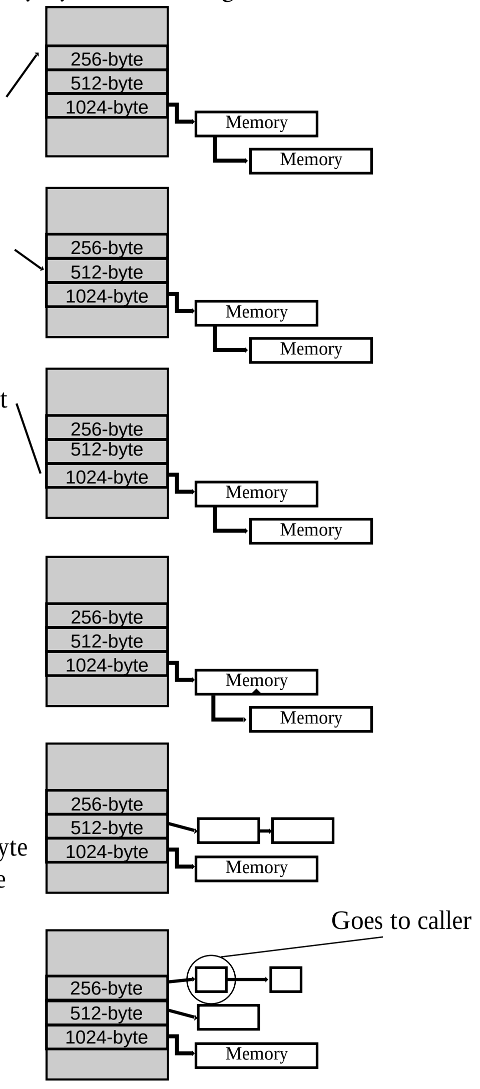
8 Divide it into two 512-byte blocks

9 Put the two 512-byte blocks into the 512-byte list.

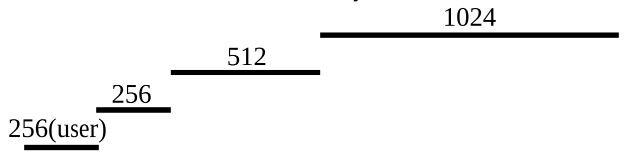
10 Divide one of the 512-byte blocks into two 256-byte blocks.

11 Insert them in the 256-byte free list.

12 Then give one of the 256-byte blocks to the caller.



Picture of memory



6.3 Fragment List and SSM

The buddy allocator does not maintain fragment lists. This improves its speed and predictability, but it complicates the use of an MMU for memory protection. The system can only maintain security if D_MinBlk is set to the MMU's page size. Programs that use the ANSI C-library's memory allocation functions will work well in that environment. C programs that use _os_srqmem() or assembly language programs that don't consider the value of D_MinBlk will get at least one MMU page for every F$SRqMem. Even a request for 16 bytes will get a full page—usually 4096 bytes. This will waste memory, but it will not cause programs to malfunction. OS-9 has always adjusted the memory size passed to the memory allocator. The buddy system allocator just rounds the allocation up further than the standard allocator. Allocation and deallocation use the same rounding rule, so rounding does not cause a memory leak even if programs take no notice of the memory size returned by F$SRqMem. If D_MinBlk is 4096, an F$SRtMem for 16 bytes will be rounded up to 4096 just like an F$SRqMem for the same amount.

Since the C-library implementation of malloc() dynamically optimizes itself around the value of D_MinBlk and most programs that use the F$SRqMem SVC directly request big blocks of memory, OS-9 runs quite well with the buddy system allocator and an MMU.

Chapter 7

Processes

In this chapter you will learn what processes are, how to create them, and how to control them. There is also a discussion of system tuning, the art of getting the best possible performance out of your computer.

Sometimes it seems that everything in OS-9 that isn't a module is a process. There is some basis for this perception.[1] Modules bind a name and other attributes to information, and processes are the operating system's way of doing things in user state.

All programs involve at least one process while they are running. The connection between processes and programs is so strong that the words "process" and "program" are often used interchangeably. Strictly speaking, a program and a process are not the same thing, but it is not worth fighting for the distinction. If you find yourself writing programs that use multiple processes, or processes that move between programs (you won't do that under OS-9), you will need to be careful with the distinction.

7.1 Starting Processes From the Shell

When you run a program from the shell:

```
$ list /dd/defs/oskdefs.d
```

the shell "forks" a process to run the ***list*** program, then pauses until the new process completes. If you change the command:

```
$ list /dd/defs/oskdefs.d >/p
```

you have some options. You can just sit there and wait until the file has printed before you can start another command, or you can break the shell out of the wait and continue

[1] There are important things that are niether processes nor modules. Interrupt service routines are active although they are not processes, and process descriptors contain data although they are not modules.

with other work while *list* runs. If you hit control-C, the shell stops waiting. You get another prompt and can run another program (start another process). You can do this because the *list* program didn't do any I/O to your terminal. If it had, the control-C would abort the *list* process as it usually does.

If you know in advance that you want the listing to run in the "background," you can tell the shell not to pause after starting the process by putting an ampersand (&) after the command:

```
$ list /dd/defs/oskdefs.d >/p&
```

You get another shell prompt immediately and the listing proceeds without your attention. If you decide that cutting the list process loose was a mistake, you can change your mind with the "w" shell directive. Just type w on the command line:

```
$ w
```

The shell waits for a process it started (child process) to terminate before continuing.

7.2 Family Relationships

Processes are related by the same names as a family. There is a parent process and there are child processes. When a process creates a new process with the `F$Fork` SVC, it is said to have "spawned" a child. Two processes spawned by the same parent are called siblings.

7.3 A Program Named Alias

It is sometimes confusing to use several different operating systems on a daily basis, particularly when the operating systems are quite similar. It tempts one to make copies of programs and rename them to match the other operating system. Copying the files containing the programs and editing them to change the module names suffices to give multiple names for one program, but it uses extra memory as it results in two functionally equivalent modules with different names. Using a small program to translate the program name saves memory and adds some power as well. The ***alias*** program can be made to start any other program. It uses a small amount of memory, but it can set the priority or optional memory values for the program it forks. With a little extra work it can add command line options as well.

```
                        nam     alias
                        ttl     Alias Program to demonstrate F$Fork SVC
                        use     <oskdefs.d>
                        opt     –l
00000101  Type          set     (Prgrm<<8)+Objct
00008001  Revs          set     (ReEnt<<8)+1
                        psect   alias,Type,Revs,1,256,Entry
00000101  AType         set     (Prgrm<<8)+Objct
00000014  AMem          set     20
0000 6469 AName         dc.b    "dir",0
00000004                align
          *
          *             This program always runs the program named dir.
          *             It will, however, appear that dir has aquired the new name, alias.
          *
          ****************
          *             Prepare to fork AName
          *             Since AName gets the parms passed to alias,
          *             move a5 to a1 and d5.l to d2
          *             If AName should get alias' priority, move d2.w to d4,
          *             otherwise use a constant priority value.
          *             Dir (particularly) likes some extra memory, so give it some.
          *
0004 3802 Entry         move.w  D2,D4           move the priority to D4 for fork
0006 303c               move.w  #AType,D0       Type for forked module
000a 7214               moveq   #AMem,D1        Memory overide for forked process
000c 2405               move.l  D5,D2           Pass parameters (length)
000e 7603               moveq   #3,D3           number of paths to pass
0010 41fa               lea     AName(PCR),a0   name of module to fork
0014 224d               move.l  A5,A1           parm pointer
0016=4e40               os9     F$Fork
001a=4e40               os9     F$Wait
001e=4e40               os9     F$Exit
00000022                ends
```

To use ***alias***, change the program name in the above psect (***ls*** might be a good alias for ***dir***) and set AName, AType, and AMem for the program you want to call. Although ***alias*** doesn't consider C-style environment variables, it *does* pass them through to the program it forks. Note that ***alias*** does not consider the path list. If `F$Fork` doesn't find the requested module (***dir***) in memory or in the default execution directory, ***alias*** will fail.

7.4 Chaining New Processes

The shell normally starts programs by forking them, but it can be made to chain to the program instead. The `F$Chain` service request eliminates the calling process and replaces it with the process requested by `F$Chain`. If you do this with the shell, you won't have a shell to return to. With other programs it is a way to save memory.

`F$Fork` followed by `F$Exit` acts almost like `F$Chain` except that between the Fork and the Exit memory is allocated for both the parent and the child process. Because of this, `F$Chain` is sometimes the only option when memory is tight.

There is also a small difference in the time required for the Fork and Chain requests. Chain is a little faster, but not enough to make a difference.

It is easy to change ***alias*** to use `F$Chain` instead of `F$Fork`. The result is more memory efficient and a little faster than ***alias*** with a `F$Fork`. Replace the three SVC calls at the end of ***alias*** with:

```
        os9     F$Chain
```

7.5 Tuning Your Operation

One of OS-9's primary functions is to divide system resources among processes. It distributes memory and I/O devices on a first come, first served basis. Time on the microprocessor is distributed according to a combination of demand and time-sliced rules. Some things can't be delayed: keyboard input, for instance, has to be read before another character is typed. OS-9 itself provides time-critical services like I/O management. The OS-9 kernel can interrupt any process, or even itself, and take whatever time it needs.

Each process has a priority number. Processes with higher priority numbers run more frequently than processes with lower priorities. For most purposes the available range of priorities is absurdly large. A small difference between the priorities of two processes can make a large difference in their relative performance, and priority values are only important in their relation to other processes' priorities. A system running two processes at priority 50 runs exactly like the same system running those processes at a priority of 5000.

Careful adjustment of process priorities can increase the efficiency of your work. OS-9 doesn't know what each process is supposed to do, or how important it is to you. Without instructions it treats all processes the same.

All processes should not be scheduled the same way. Some processes don't need frequent access to the processor. A process that is running your printer is a good candidate for a low priority. You may think that 160 characters per second is fast; the computer doesn't. A process that has nothing to do except send 160 characters to the printer each second spends most of its time waiting. Even if it isn't right on the spot with a character to be written, it's no big deal if the printer has to wait a fraction of a second. Set the priority for this type of process low compared to other processes.[2] It gets a crack at the processor every now and then. During its time slice the process feeds the device driver for the printer a buffer-full of characters. This buffer supplies the driver with output for the printer until the process's next turn.

A process that interacts with the world often needs high priority. It probably won't use most of its time slices because it will be waiting for input. (Actually, it won't get any CPU time at all if it's waiting for input.) When an event occurs in the world, the process waiting for that event should respond fast. Text editors usually sit around waiting for a keystroke, but it would be annoying if a key took half a second to register, or the screen updates took a few seconds. People, and other impatient real-world entities, need attention! Make sure your computer knows about your requirements by assigning a high priority to any programs that respond to impatient parts of the world.

Programs like ***copy***, assemblers, and particularly the C compiler take all the resources they can get. If you want to run them with other processes, protect the other processes by giving hard-working processes a lower priority than the others.

As a rule, programs that do a lot of computation need to be interrupted by a timer and put at the back of the queue. Processes that do a lot of I/O, particularly SCF-style I/O, are already slowed by the device they are driving. They don't need to be controlled artificially. (Though they can tolerate low priorities with little degradation.)

7.5.1 Summary

Process priority has several uses. A low priority can tame CPU-intensive programs, or tuck a task that you aren't impatient about down where you won't notice its impact on the system. If you want alert responses to something you're doing, a text editor or maybe real-time graphics, a high priority insures it lots of attention from the CPU.

You won't speed anything up by assigning all your processes high priority. As the word priority implies, you have to rank processes. The difference between the priorities of processes in the system is the only aspect of priority that matters.

[2] A small difference in priority numbers is enough to have a substantial effect. Giving a process a priority five or ten below other processes pushes it well into the background.

Chapter 8

Signals

In this chapter you will learn what signals are and how to control them.

Signals can be used for interprocess communication, for communication from interrupt service routines, and for communication between the operating system and processes. In each case, signals act somewhat like hardware interrupts. When they are not masked, signals can interrupt a process after any instruction. Signals can be used to indicate exceptional conditions (like "time to clean up and exit") or as a fairly ordinary inter-process communication tool. With a handshaking protocol, signals can even be converted into a synchronous communication mechanism, but events or pipes are usually more suitable for synchronous communication.

The operating system can send signals to processes on its own behalf. Some signals, such as alarms and signal on data ready, are requested by processes. OS-9 sends other signals without special prompting: keyboard abort, keyboard interrupt, and a modem hangup signal. There is also a system abort signal that never gets to a process. It kills the process without warning. Keyboard abort, hangup, and keyboard interrupt kill unprepared processes, but a signal intercept routine can catch these signals and do whatever you like with them (including ignoring them).

A process can send most signals to any other process, but the *kill* signal is restricted. Every process carries a user and group number.[1] A process can only send a kill signal to processes with the same user and group. This prevents people from accidentally killing another user's processes. The super user (group 0) can kill any process; this allows the super user to kill out-of-control processes and gives servers running under group 0 unrestricted communication with all processes.

[1] User and group numbers come from the password file. For each login the ***login*** utility starts a shell with user and group numbers drawn from the password file, and the numbers are passed through `F$Fork` to each new process that the user starts.

Signals are a peep-hole that OS-9 leaves between processes. It is such a narrow communication channel that it takes ingenuity to use, but it is enough to build powerful systems of processes. The building blocks are

- the F$Send system service request, which sends a specified signal to a specified process;
- the F$RTE request, which returns from the signal intercept routine to OS-9;
- the F$Icpt request, which sets up a signal-intercept routine;
- F$SigMask, which prevents signals from being delivered;
- F$Sleep, which causes a process to wait for a signal;
- and F$SigReset, which causes OS-9 to pop a level of F$RTE state without doing an F$RTE.

Without an intercept routine, a process is killed by the first (non-wakeup) signal it receives. The intercept routine doesn't have to be very complicated. An intercept routine containing only an F$RTE (return from exception) SVC is sufficient to prevent the process from being killed by any signal it receives.

A process need not sleep to receive signals, but frequently processes run of out of work while waiting for a signal. If no useful work is available, a process should sleep, wait for a child process to complete, or wait on an event. A sleeping or waiting process doesn't use any CPU time, and it responds immediately to signals.

The following example intercepts signals. It sets up an intercept routine, then waits until a signal arrives. When it receives a signal, ***SigTrap*** writes a brief message explaining the signal and calls F$Exit.

Only under special circumstances does the A6 register need to be set before calling F$Icpt. It is so painful to have offsets from A6 different in the main program and the intercept routine, that the small performance improvements that might come from adjusting A6 (smaller offsets from A6 in the intercept routine) are generally ignored. The only programs that adjust A6 before calling F$Icpt are those rare assembly language programs that don't use A6 as the base register for global storage.

Sleeping with D0 set to zero means sleep forever. Since any signal will wake a sleeping process, sleep "zero" actually means sleep until a signal arrives.

The F$PErr service request prints an error message based on the number in D1. This service request formats the error number.

```
        nam     SigTrap
        ttl     Display signals
        use     <oskdefs.d>
```

```
                        opt     –l
00000101 type           set     (Prgrm<<8)+Objct
00008001 Revs           set     (ReEnt<<8)+1
                        psect   SigTrap,type,Revs,1,200,Entry
0000 5369 Name          dc.b    "SigTrap"
0007   0d               dc.b    $0D
         ****************
         * Messages
         *
0008   0a Int1          dc.b    $0A
0009 5761               dc.b    "Wake up"         we won't see this one
0010   0d               dc.b    $0D
0011   0a Int2          dc.b    $0A
0012 4b65               dc.b    "Keyboard Abort"
0020   0d               dc.b    $0D
0021   0a Int3          dc.b    $0A
0022 4b65               dc.b    "Keyboard interrupt"
0034   0d               dc.b    $0D
0035   0a Intx          dc.b    $0A
0036 4d69               dc.b    "Misc. Signal"
0042   0d               dc.b    $0D

                        vsect
0000 0000 SigCode       dc.w    0                 Store intercepted signals here
00000002                ends

0044 41fa  Entry        lea     Trap(PCR),A0      Address of intercept routine
0048=4e40               os9     F$Icpt            Set up intercept trap
004c 6550               bcs.s   Error
004e 41fa               lea     Name(PC),A0       Prompt for a signal
0052 7207               moveq   #7,D1             Length of the prompt
0054 7001               moveq   #1,D0             Send it out std output
0056=4e40               os9     I$Write           Write the prompt
005a 6542               bcs.s   Error             Branch if error
005c 7000               moveq   #0,D0
005e=4e40               os9     F$Sleep           wait for a signal
0062 653a               bcs.s   Error             Possible E$NoClk
0064 302e               move.w  SigCode(A6),D0    check signal code
0068 b07c               cmp     #1,D0             if it was 1
006c 6606               bne.s   S2
006e 41fa               lea     Int1(PC),A0       write message Int1
0072 6020               bra.s   End
0074 b07c S2            cmp     #2,D0             if signal was 2
0078 6606               bne.s   S3
007a 41fa               lea     Int2(PC),A0       write message Int2
007e 6014               bra.s   End
0080 b07c S3            cmp     #3,D0             if signal was 3
0084 6606               bne.s   Sx
0086 41fa               lea     Int3(PC),A0       write message Int3
```

```
008a 6008              bra.s   End
008c 41fa   Sx         lea     Intx(PC),A0      Unknown signal
0090=4e40              os9     F$PErr
0094 7250 End          moveq   #80,D1           Max length
0096 7001              moveq   #1,D0            std out
0098=4e40              os9     I$WritLn         Write signal description
009c 7200              moveq   #0,D1            Clean return
009e=4e40 Error        os9     F$Exit
00a2 3d41  Trap        move.w  D1,SigCode(A6)   save the signal code
00a6=4e40              os9     F$RTE
000000aa               ends
```

8.1 An Undocumented Feature

The *OS-9 Technical Manual* states that the kernel sets the values of D1 and A6 before calling the intercept routine. It does not mention that D0 is also set to the number of queued signals for that process. Since it counts the signal being delivered as one of the queued signals, a value of one in D0 indicates that there are no waiting signals. The C interface to F$Icpt hides this value. The intercept() function buffers the intercept routine inside another function that hides the number of signals in the queue and issues an F$RTE when the catcher returns.

The following replacement for _os_intercept() changes the rules for intercept routines. If a program uses OS9intercept(), the intercept routine receives two arguments and it must call F$RTE to return. If the intercept routine simply returns, bad things will happen.

```
                       nam      OS9intercept
                       ttl      OS9intercept
                       psect    OS9intercept,0,0,0,0,0
          * d0 points to the function to use as the intercept routine
0000 4e55  OS9intercept: link   a5,#0
0004 2f08              move.l   a0,-(sp)
0006 2040              move.l   d0,a0
          * a0 and a6 are set
0008=4e40              os9      F$Icpt
000c 7000              moveq.l  #0,d0 Return value
000e 205f              move.l   (sp)+,a0
0010 4e5d              unlk     a5
0012 4e75              rts

          * This function knows it will be called from a C function,
          * so it does magic to unwind the stack.
          *
```

```
0014 4e5d  rte:     unlk    a5
0016=4e40           os9     F$RTE
0000001a            ends
```

A C program using OS9intercept( ) would follow this general form:

```
#include <stdio.h>
#define TRUE      1

Catcher(int QLength, short Signal)
{
    printf("Signal code: %d. Queue length: %d\n", Signal, QLength);
    fflush(stdout);
    rte( );
}

main( )
{
    printf("Ready\n");
    OS9intercept(Catcher);
    while(TRUE)
        sleep(0);
    exit(0);
}
```

8.2 Masking Signals

Ordinarily, a process can receive a signal any time it is not in its signal intercept routine. Both aspects of this rule can be inconvenient at times. A process may wish to delay returning from its intercept routine, but be unwilling to risk delaying a signal; such processes need to unmask signals without executing an F$RTE. Other processes may wish to share a complex data structure between the intercept routine and the mainline code. The mainline code can only safely update such shared data structures with atomic operations (e.g., tas), or by masking signals to create new atomic operations like:

```
_os_sigmask(1);                                          /* mask signals */
OldHead = QHead;
if(++QHead >= EndOfBuffer)
    QHead = 0;
if(QHead == QTail){                                          /* Overflow */
    QHead = OldHead;
    Updated = FALSE;
}else {
    Array[QHead] = NewData;
    Updated = TRUE;
}
_os_sigmask(−1);                                          /* Unmask signals */
```

A process may also wish to mask signals to achieve slightly more deterministic performance during periods with exceptionally rigorous timing constraints.

```
_os_sigmask(1);
/* A block of code that must execute with minimal interruptions */
_os_sigmask(−1);
/* Service signals */
_os_sigmask(1);
/* Another block of code that must execute with minimal interruptions */
_os_sigmask(−1);
```

Of course, masking signals to prevent the signal intercept routine from running is futile if other processes steals the processor through timeslicing. A process with this kind of timing constraint will set D_MinPty to prevent any other process from running. Combining D_MinPty with _os_sigmask(), the code protected by _os_sigmask() can only be interrupted by hardware interrupts and the associated OS code.

The signal mask count, P$SigLvl in the process descriptor, is an unsigned byte value. When it is non-zero, the process' intercept routine is not called.[2] The F$SigMask system call can operate on the value of P$SigLvl in three ways:

1. When F$SigMask is called with DI equal to 1, the value of P$SigLvl in the calling process' process descriptor is incremented by one.

2. When F$SigMask is called with DI equal to −1, the value of P$SigLvl in the calling process' process descriptor is decremented by one.

3. When F$SigMask is called with DI equal to 0, P$SigLvl in the calling process' process descriptor is cleared to zero.

Any other value of DI causes an illegal parameter error.

Attempts to increment the byte past 255 or decrement it below 0 are silently ignored.

A function might include a sequence of operations that must be performed without interruption by the signal intercept routine. If the function is always called with signals

[2] See section 8.10 for details on the special treatment of P$SigLvl for some signals.

masked, it can safely do nothing. But, if the function may be called with signals either masked or unmasked, it must mask signals. The function should unmask signals before returning, but must not use _os_sigmask(0) to clear the signal mask; that would unmask signals even when returning to code that expected masked signals.

Unless a process definitely intends to unmask signals, it should use _os_sigmask(−1). This returns the signal mask to the state before the most recent _os_sigmask(1). A zero parameter, _os_sigmask(0), is for those occasions when signals should be unmasked regardless of the process' past.

F$SigMask calls from intercept routines are treated like all other F$SigMask calls. The intercept routine can unmask signals by calling F$SigMask with DI equal to −1, or it can cause signals to be masked even after the intercept routine calls F$RTE[3] by calling F$SigMask with a 1. This latter technique has potential for causing nearly impenetrable bugs, so don't do it unless there is no reasonable choice.

The sequence:

```
_os_sigmask(1);
sleep(0);
```

seems like a sure way to lock up a process. It masks signals, then sleeps waiting for a signal. Not only does a mask/sleep sequence work without locking the system, it's the trivial case of a common construct. Sleeping with signals masked works because F$Sleep unmasks signals. Without this feature of F$Sleep, some signal-driven code would be almost impossible to write.

8.3 Servicing Signals in the Mainline

The structure of a typical signal-driven program is:

```
_os_sigmask(1);
while(TRUE){
    CallForSignals(a);
    CallForSignals(b);
    CallForSignals(c);
    sleep(0)
    while(SigCt[A]-- >0) ServiceA();
    while(SigCt[B]-- >0) ServiceB();
    while(SigCt[C]-- >0) ServiceC();
    _os_sigmask(1);
}
```

[3] In C code, returning from a signal intercept routine automatically calls F$RTE.

```
SigCatch(sig)
int sig;
{
    if(sig > FIRST_SIGNAL)                    /* Is this an interesting signal? */
        ++SigCt[sig];
}
```

1. The process masks signals.
2. Then the process requests signals from the I/O devices and other processes with which it interacts.
3. When the process sleeps, any signals that have been delivered since signals were masked are delivered. Because signals were masked before the process called for any signals, no signals will arrive before the sleep().
4. All waiting signals call the intercept routine, SigCatch(), as soon as sleep unmasks interrupts. If no signals are waiting, F$Sleep waits until a signal arrives.
5. SigCatch increments counters for each signal it receives.
6. When SigCatch() returns and finds no signals waiting, OS-9 resumes the mainline after the sleep() with signals unmasked.
7. Service all the signals that arrived during the sleep().
8. Mask signals, and repeat.

CallForSignals() should send a signal when it is called with work pending even if it has already signaled for that particular piece of work. If it doesn't do that, the driving loop must be restructured like:

```
_os_sigmask(1);
while(TRUE){
    CallForSignals(a);
    CallForSignals(b);
    CallForSignals(c);
    sleep(0)
    _os_sigmask(1);
    while(SigCt[A]— >0) ServiceA();
    while(SigCt[B]— >0) ServiceB();
    while(SigCt[C]— >0) ServiceC();
}

SigCatch(sig)
int sig;
{
    if(sig > 255)
        ++SigCt[sig];
}
```

The new structure has _os_sigmask( ) before all the service code instead of at the end of the main loop. This prevents a signal for serviceA( ) that arrives after SigCt[A] has been reduced to zero from being ignored until some other signal knocks the next iteration of the loop out of the sleep( ).

If each CallForSignals( ) calls for one signal and no other signals are sent until the next CallForSignals, the template can be simplified:

```
_os_sigmask(1);
while(TRUE){
    CallForSignals(a);
    CallForSignals(b);
    CallForSignals(c);
    sleep(0)
    _os_sigmask(1);
    if(SigCt[A]— >0){
        ServiceA( );
        SigCt[A] = FALSE;
    }
    if(SigCt[B]— >0){
        ServiceB( );
        SigCt[B] = FALSE;
    }
    if(SigCt[C]— >0){
        ServiceC( );
        SigCt[C] = FALSE;
    }
}

SigCatch(sig)
int sig;
{
    if(sig > 255)
        SigCt[sig] = TRUE;
}
```

8.4 Servicing Signals in the Intercept Routine

A signal-driven process may choose to enclose all the signal-driven code in the signal intercept routine. Since signals are masked in the intercept routine, the code there can service a signal and set up for the next signal without worrying about missing a signal between the time the process calls for the signal and the time it sleeps.

The following is a signal-driven program that runs entirely in the signal intercept routine after a minimal setup section. It is a program I wrote to kick off a contest on BIX. The object was to write a telecom program that would fit on one page. The result of the contest was a program that fit on a page with room for some comments. It was, however, even more cryptic than the following:

```
                        nam     j
                        ttl     Simplest communication program
        *
        * Attach stdin/out to the named device
        *
                        use     <oskdefs.d>
                        opt     –l
                        psect   j,(Prgrm<<8)+Objct,(ReEnt<<8)+0,1,256,Entry
00000400 BuffSize       equ     1024
000003ff SizeMask       equ     $3ff
0000000f EndChar        equ     $0f             control-O
                        vsect
00000000 Mpath          ds.w    1
00000002 Buffer:        ds.b    BuffSize
00000402 PathOpts:      ds.b    128
00000482 SPathOpts:     ds.b    128
00000000                ends
00000000                align
0000 204d Entry:        move.l  a5,a0           use parm ptr as path ptr
0002 7003               moveq   #3,d0           update mode
0004=4e40               os9     I$Open
0008 6528               bcs.b   Error
000a 3d40               move.w  d0,Mpath(a6)
000e 6166               bsr.b   CSetOpts        set options for Mpath
0010 760f               moveq   #EndChar,d3
0012 7000               moveq   #0,d0           stdin path number
0014 6162               bsr.b   SetOpts         set options for stdin
0016 41fa               lea     SigRtn(PC),a0   handler
001a=4e40               os9     F$Icpt          set up intercept routine
001e 302e               move.w  Mpath(a6),d0
0022 6112               bsr.b   SetSig          for modem path
0024 7000               moveq   #0,d0
0026 610e               bsr.b   SetSig          for stdin
0028 7000 Loop:         moveq   #0,d0
002a=4e40               os9     F$Sleep
002e 64f8               bcc.b   Loop

0030 7200 Done:         moveq   #0,d1           clear error code
0032=4e40 Error:        os9     F$Exit

0036=7200SetSig:        moveq   #SS_SSig,d1     setstat code
0038 7408               moveq   #8,d2           Signal == 8
003a=4e40               os9     I$SetStt
003e 4e75               rts
```

```
0040 7000 SigRtn:   moveq   #0,d0
0042 362e           move.w  Mpath(a6),d3
0046 610a           bsr.b   IO
0048 2003           move.l  d3,d0             d3 is already Mpath
004a 7601           moveq   #1,d3
004c 6104           bsr.b   IO
004e=4e40           os9     F$RTE

0052=7200 IO:       moveq   #SS_Ready,d1
0054=4e40           os9     I$GetStt
0058 651a           bcs.b   IOX
005a 41ee           lea     Buffer(a6),a0
005e c27c           and.w   #SizeMask,d1
0062=4e40           os9     I$Read
0066 653e           bcs.b   SigDone
0068 2801           move.l  d1,d4
006a 61ca           bsr.b   SetSig
006c 2204           move.l  d4,d1             restore read size
006e 2003           move.l  d3,d0             choose write path
0070=4e40           os9     I$Write
0074 4e75 IOX:      rts

          * d0 is path, d3 is the end character
0076 7600 CSetOpts: moveq   #0,d3             set default end char (none)
0078 2f08 SetOpts:  move.l  a0,–(sp)
007a=7200           moveq   #SS_Opt,d1
007c 41ee           lea     SPathOpts(a6),a0
0080=4e40           os9     I$GetStt
0084 65ac           bcs.b   Error

0086 41ee           lea     PathOpts(a6),a0
008a=4e40           os9     I$GetStt
008e=74ff           moveq   #(PD_OVF–PD_UPC)–1,d2 number of bytes
0090 43e8           lea     1(a0),a1          point a1 at PD_UPC
0094 4219 InitOpt:  clr.b   (a1)+
0096 51ca           dbra    d2,InitOpt
009a=1d43           move.b  d3,PD_EOF–PD_DTP+PathOpts(a6) set end char
009e=4e40           os9     I$SetStt
00a2 205f           move.l  (sp)+,a0
00a4 4e75           rts

00a6 7000 SigDone:  moveq   #0,d0
00a8=7200           moveq   #SS_Opt,d1
00aa 41ee           lea     SPathOpts(a6),a0 restore the old path options
00ae=4e40           os9     I$SetStt
00b2 6000           bra.w   Done
000000b6            ends
```

J opens the modem path and sets path options on its paths, then calls for signal on data ready on its two input paths and sleeps. The main program just keeps going back to sleep every time it wakes up unless it wakes up with carry set; that would be a big surprise since there is no error code returnable by an untimed sleep. All the real work is done from inside the intercept routine.

J relies on three characteristics of OS-9's signal handling:

- Send signal on data ready sends a signal immediately if there is data in the buffer when the setstat call is made.
- Signals are masked while *j* is in its intercept routine.
- Though the setstat call may return an error, it does no harm to call for a signal from a device that already has set send signal on data ready.

Assume that there is some data waiting in the modem device's input buffer when *j* starts. As soon as *j* executes the SS_SSig system call the driver sends a signal and *j* finds itself in the intercept routine. There it moves everything it finds in the modem to the terminal and resets SS_SSig on that device. If there is data at the keyboard, it moves all of that data to the modem and resets SS_SSig on the keyboard device. This may generate more signals immediately, but they are masked because the process is in its intercept routine.

Eventually the mainline of the program reaches the sleep and loops there until *j* exits. The intercept routine awakens when there is work to do (and sometimes when there *was* input available that was handled by the previous iteration). It moves data from device to device and returns to the OS. The signal intercept routine acts like an interrupt service routine in that it responds quickly to input on either path. Like an interrupt service routine with multiple devices on one interrupt vector, the intercept routine must poll the devices to determine which sent the signal.

Even program termination is driven from the intercept routine. When the intercept routine calls F$Exit instead of F$RTE, OS-9 terminates the program.

The *OS-9 Technical Manual* recommends keeping the signal intercept routines small and fast. Fast intercept routines are certainly a good idea, but support for queued signals and signal masking and unmasking makes "non-trivial" intercept routines an alternative worth consideration. Simply, when a process enters its signal intercept routine signals are masked, with P$SigLvl set to 1. If the process doesn't unmask signals explicitly or with an F$RTE,[4] they will stay masked. That will keep other signals from being serviced. If the convenience of a long intercept routine is worth keeping signals masked for a long time, you can make that choice. Unmasking signals inside the intercept routine is also possible, but can lead to performance problems (see section 8.5).

[4] F$RTE does not unconditionally unmask signals. It decrements the signal mask counter. Just like _os_sigmask(−1), F$RTE can leave signals masked.

The most extreme cases of long intercept routines are ported from Unix. There, programmers habitually longjmp() out of the intercept routine back to the main program. They never *return* from the intercept routine. OS-9 supports that technique provided that the program is written with care:

- Unmask signals before or soon after longjmp()'ing.
- Call F$SigReset. This can be done before the longjmp(). The F$SigReset can be done as early as the first instruction in the intercept routine if it always either longjmp()s out of the intercept routine or uses exit() to end the process entirely,
- If the program uses the C I/O library, realize that a signal may interrupt C I/O code in the middle of an operation. I/O data structures may be inconsistent. This can be solved by:
  - Using low-level I/O, or
  - Masking signals around each call to the C I/O library.

The following code fragment illustrates one way an intercept routine might correctly longjmp() into mainline code.

```
    if(setjmp(buf1) != 0)
        _os_sigmask(-1);                                /* Unmask signals */
...
InterceptRtn(code)
int code;
{
    switch(code){
        case CODE1:
            _os_sigreset();
            longjmp(buf1, 0);
        case CODE2:
            _os_sigreset();
            longjmp(buf2, 0);
        case CODE3:
            _os_sigreset();
            longjmp(buf3, 0);
        default: /* ignore */
    }
}
```

By unmasking signals after the longjmp(), the code fragment prevents possible stack trouble. OS-9 places about 70 bytes of "stuff" on the stack when it calls an intercept routine. If signals are unmasked while the process is in the routine, another signal could add 70 more bytes to the stack. Enough signals could cause stack overflow. This is avoided by unmasking signals *after* the longjmp. When longjmp() resets the stack it removes the "stuff" OS-9 put there.

8.5 The Signal-State Stack

It takes OS-9 a long time to store the process state[5] on the process' stack, but sometimes it is necessary. If a process unmasks signals inside its intercept routine it can receive another signal and recursively call the intercept routine. Since the program will eventually use F$RTE to return from each nested intercept routine, OS-9 needs to stack the states.

The states do not have to be on the process' stack. They could be stored in a linked list of dynamically-allocated memory or they could be stored on the one of the system stacks. Allocating memory for the process state each time OS-9 calls an intercept routine would be too slow. Memory allocation is one of the slower kernel services. The system stack looks like an attractive place to stack process states, but it has a pitfall; it would require stack checking in all system calls. The performance of every system call would suffer. Since the stack usage of the kernel is well-understood, it is able to do without stack checking except in the recursive F$CmpNam SVC. If some unknown amount of the system stack was used for signal intercept states, every call would need to check the stack. After enough recursions, that process' system stack would get so full that only simple SVCs would work, then it would die.

The user stack is already allocated and its size is set by the programmer according to how the program is expected to behave. It is the obvious place for signal state. But there are still two problems:

- Moving the process state onto the stack takes a lot of time. It's already stored in system state and recursion of intercept routines is rare. It doesn't seem good to make all processes pay a heavy price for the few processes that unmask signals in the intercept routine.

- The kernel can tell when the signal state makes the stack overflow by so much that it runs out of that process' storage altogether, but it cannot tell when the stack will overflow just enough that the state will write onto the process' static storage.

The problems with signal state are addressed as follows:

[5] The process state that is stored for a signal intercept routine includes all the process' MPU registers, a total of 72 bytes of data. It also includes the FPU registers if the FPU is active. The CPU and FPU state together user 168 bytes of stack space.

- *One* state is stored in system state. The vast majority of the time states are not stacked, so most programs get optimum performance because they never have to store states on the user stack.
- If the signal intercept routine is called recursively, the additional states are stored on the user stack.[6]
- A program that simply longjmp()'s out of the intercept routine and unmasks signals looks to the kernel like it remains in the intercept routine. It has not called F$RTE. Any state stored on the user stack is cleared from the stack by the longjmp(), but the kernel is not informed. Code that uses longjmp() this way will work, but it will not run as fast as possible. Since the kernel thinks it's seeing recursive use of the intercept routine, it will store states on the user stack.
- The F$SigReset SVC tells OS-9 that there should be no stacked states. The next call to the intercept routine will have its state saved (fast) in the system.

F$SigReset is simple and fast. It does not detect errors and cannot be used to remove just one or two levels of recursion from the stack. These would be nice features, but they can be supported outside the kernel. If F$SigReset is used in a library routine (e.g., Fancy_Reset()), the routine can count calls to Fancy_Reset(), _os_rte(), and the intercept routine, and only call F$SigReset when it sees that the state stack has been emptied. It can also return an error when a program calls Fancy_Reset() with an empty state stack. There's no requirement for OS help.

If for some reason a program *wants* to have all states saved on the process' stack, it can force that by longjmp()ing out of an intercept routine once and never doing a F$SigReset.

Usually each longjmp() out of an intercept routine should be accompanied by an _os_sigreset(). It can be placed after or before the longjmp(), but it should be placed before the _os_sigmask() that will also accompany the longjmp(). If the _os_sigreset() is not done before signals are unmasked, the process risks a recursive call to the intercept routine.

The cost of F$SigReset is about twice the cost of transferring state onto the user stack. There might be times when it is better to let the next signal pay that price than to use the time for F$SigReset now.

To review:

- F$SigReset is seldom required. It is mainly a performance optimization for programs that longjmp() out of intercept routines, but see section 8.6 for another reason to use F$SigReset.

[6] If the state overflows the stack, the intercept routine has to catch it. The kernel will not.

- Except when the kernel thinks it is servicing recursive calls to the signal intercept routine, no state is saved on the process' user stack.
- F$SigReset may be called at any time, but for best effect call it before signals are unmasked.

8.6 An Obscure Problem

The signal intercept nesting counter is a long word. If a fast system did nothing but send signals to a process, that process could overflow the counter in a day or two. Even if the entire four gigabyte address space was devoted to the process' stack, the stack would overflow long before the nesting counter overflowed so it is generally an unrealistic problem. But, a program that mixes longjmp( ) and F$RTE exits from intercept routines and never uses F$SigReset can overflow the counter without overflowing the stack.

The counter is not checked for overflow, so a process could wrap the counter to zero and use F$RTE to restore the ancient state saved on the system stack. The chances of this are remote, but not zero. It is the kind of bug that strikes programs only after they are completely trusted. Programs that use F$SigReset each time they longjmp( ) out of an intercept routine are immune to this trouble. The conditions for this bug include:

- The program must longjmp( ) out of a signal intercept routine at least four billion times.
- The program must use both F$RTE and longjmp( ) to exit from signal intercept routines.
- The program must not call F$SigReset, or must use it less frequently than once in every four billion longjmp( )s.

8.7 Async Safety

Signal intercept routines bring one of the trickiest aspects of kernel programming to user-state code. Unless you mask signals, a signal can occur after any machine instruction. This is invisible if the signal intercept routine doesn't touch any data structures used by the mainline, but since intercept routines usually need to communicate with the mainline, the mainline and the intercept routine generally need to share some data structures.

Few data structures can be updated in one machine instruction, and if an intercept routine gets control when a data structure is half-updated ("in an inconsistent state"), both the intercept routine and the mainline will be unhappy.

If your code manages its data structures so they work with intercept routines, the code and structures are called *async safe.* There are several ways to achieve async safety.

- You can use async-safe algorithms. These are theoretically attractive, and sometimes there is no good alternative, but async-safe algorithms tend to be slow and complicated.
- You can mask signals whenever you update a shared data structure in the mainline code.
- You can use data structures that can be updated with a single machine instruction. The frequently-used instructions are:
  - `move` to memory or memory-to-memory
  - `addq` to memory
  - `subq` to memory
  - `bset`
  - `bclr`
  - `tas`

  The more sophisticated 68000-family processors support additional atomic instructions—`cas` for updating a singly-linked list, and `cas2` for doubly-linked lists—but these operations don't do the entire update in one instruction. They do the last part of the update after insuring that the update has not been interrupted. Here, for example, is the code to update a singly-linked stack:

```
* pointer to new node is in a0
            move.l  a0,d1            copy address to a data reg
retry       move.l  TOS(a6),d0       Get TOS
            move.l  d0,next(a0)      attach stack to new node
            cas     d0,d1,TOS(a6)
            bne.b   retry
```

  The move before the `cas` points the new node to the node at the top of the stack. The `cas` checks to see whether the top of stack pointer has changed since it was saved in D0, and if it is unchanged, points TOS at the new node. If the TOS was changed, the algorithm knows it was interrupted and tries again.

In some cases you have no choice but to mask signals. C library routines don't mask signals, and they are not coded with consideration for async safety. In particular, it is unsafe to use standard I/O functions in the signal intercept routine unless you mask signals around each call to a standard I/O function in the mainline:

```
        _os_sigmask(1);
        putchar('*');
        _os_sigmask(−1);
```

You can avoid this requirement by using low-level I/O throughout your program or using distinct I/O paths in the intercept routine.

For paths that cannot seek, you can achieve async safety by using low-level I/O[7] in the intercept routine and standard I/O in the mainline. Using both standard I/O and low-level I/O produces bad results on RBF files even if intercept routines are not involved.

Flavors of `move` and the bit setting and clearing instructions safely manipulate data structures containing from 1 bit to 32 bits of data. You can use this to pass simple data between the intercept routine and the mainline.

`Addq` and `subq` update shared counters. With care, `addq` and `subq` are also enough to manage some types of shared array of data.

The intercept routine runs with signals masked, so it can run without fear of interruption. In most cases, this means that you can use data structures that are updated only by the intercept routine without much concern. The mainline has to realize that the data structure may change as it looks at it, but the mainline never sees the data structure half updated.

The general rules for async safety are:

- Minimize data structure sharing between the intercept routine and the mainline.
- Mask signals or use a single-instruction update whenever you update a shared data structure in the mainline.
- Unless you are ready to think hard about worst-case situations, also mask signals when you read shared data structures in the mainline code.

8.7.1 Horrible Example

Consider a simple, shared, singly-linked stack that is updated with the following algorithms:

```
        * pointer to new node is in a0
1       Push    move.l  TOS(a6),a1      Get TOS
2               move.l  a1,next(a0)     attach stack to new node
3               move.l  a0,TOS(a6)
4               rts
```

[7] Low-level I/O is the set of C I/O functions that use the path number instead of a FILE pointer.

```
5     Pop    move.l  TOS(a6),a0
6            move.l  next(a0),TOS(a6)
7            move.l  a0,d0            return popped node ptr in d0
8            rts
```

The mainline is busy pushing node *x* onto the stack. The node at the top of the stack is node *a*. The mainline executes lines one and two, then it is interrupted by the intercept routine. The intercept routine pops *a* off the stack. When the mainline resumes, it points TOS at *x* and returns. The stack is now destroyed.

TOS points at *x* and *x* points at *a*. The node named *a* was at the top of the stack when the mainline started pushing *x*, but now it has been popped by the intercept routine and is somewhere else. (For an extra horrible example, assume the intercept routine pushed it into a different stack.) The stack might have included hundreds of nodes, but after mainline finishes its push function, the stack contains only *x*. All the other nodes are lost. Nothing points to the node that used to be after *a*.

If the mainline had masked signals before running push or used the `cas` protocol shown above, the integrity of the stack would have been preserved.

8.8 Broadcast

Signals sent to process zero are actually broadcast to all processes with the same user and group as the sending process. Broadcast carefully avoids sending a signal to the broadcasting process, so if *every* process belonging to the user should get the message, the sending process has to send an extra signal to itself.

The built-in shell command ***kill*** can be used to kill all the user's processes except the shell.

```
$ kill 0
```

broadcasts a kill signal to all the user's processes except that shell. This is a good way to handle the processes belonging to a telecommunicating user who simply hangs up the phone instead of cleaning up and logging out. The telecom program will receive an S$Hangup from the modem port. It can then broadcast either the S$Hangup or S$Kill to all other processes belonging to the user.

It's also a convenient way for the super user to clean someone out of the system:

```
/* KillUser */
#include <stdio.h>
#include <process.h>
#include <types.h>
#include <errno.h>
```

```
#include <signal.h>
#include <const.h>

typedef u_char boolean;
/*
    Prototypes
*/
boolean SuperP(void);

main(int argc, char **argv)
{
    u_int16 Usr, Grp;
    owner_id GrpUsr;


    /*
        Get the grp.usr to kill from the command line.
    */
    if(sscanf(argv[1], "%d.%d", &Grp, &Usr) != 2){
        fprintf(stderr, "%s:  requires an argument of the form <usr>.grp\n",
        argv[0]);
        exit(1);
    }

    /*
        Combine the group and user into one number.
    */
    GrpUsr.grp_usr.grp = Grp;
    GrpUsr.grp_usr.usr = Usr;

    /*
        Don't let the caller kill the super group.
    */
    if(Grp == 0){
        fprintf(stderr, "Killing the super group is a bad idea\n");
        exit(1);
    }

    /*
        Make sure we're being called by the super user.
    */
    if(!SuperP()){
        fprintf(stderr, "%s:  may only be run by the super user.\n", argv[0]);
        exit(1);
    }
    /*
        Change to the grp.usr we want to kill
    */
     if((errno = _os_setuid(GrpUsr)) != SUCCESS){
        fprintf(stderr, "%s: setuid to %d.%d failed.\n", argv[0], Grp, Usr);
        exit(errno);
    }

    /*
        And kill all the processes except this one.
    */
     if((errno = _os_send((process_id)0, SIGKILL)) != SUCCESS){
        perror("broadcast signal");
        exit(errno);
    }
    exit(0);
}


boolean SuperP()
{
    process_id x1;
    u_int16 x2;
    u_int16 Group;
     (void)_os9_id(&x1, &x2, &Group, &x2);
    return(Group == 0);
}
```

8.9 Queued Signals

OS-9 does not “throw signals on the floor” when signals are sent to a process that has a signal pending; it keeps pending signals in a queue and delivers them in the order they were sent. This is a powerful feature. It means that even processes that run at low priority or mask signals extensively see every signal sent to them.

Queuing signals can be quite expensive (depending the number of memory colors and the amount of memory fragmentation). It is best to assume that sending a signal to a signal queue can take ten times as long as sending an unqueued signal.[8] Signal queuing also causes OS-9 to mask interrupts for a comparatively long interval.

[8]It would be very hard to make a queued signal take 10 times as long to send as an unqueued signal. The point is that queued signals are a feature that should not be used lightly.

Signal queuing occurs when high-priority processes send rapid sequences of signals to low-priority processes or when any process masks signals for a long time compared to the interval at which signals are sent to it. To avoid these situations:

- Reduce the length of stretches of code that mask signals.
- If a low priority process is expected to service signals from a high priority process, raise its priority. Especially if the process is sleeping while it waits for signals, raising the priority is painless. A sleeping process doesn't use any cycles until it is awakened by a signal. The following code is a stub for the mainline of a signal handler:

```
#include <stdio.h>
#define TRUE                    1
#define HIGH_PRIORITY           400
#define LOW_PRIORITY            50

main()
{
    int myid;
    myid = getpid();
    printf("Ready\n");
    OS9intercept(Catcher);
    while(TRUE){
        setpr(myid, HIGH_PRIORITY);
        sleep(0);
        setpr(myid, LOW_PRIORITY);
    }
    exit(0);
}
```

  Depending on the desired result, the priority of the process could be set back to low priority in the mainline as shown in the example, or in the intercept routine. The response of the signal handler can also be varied by setting the priority low before or after performing any computation motivated by the signal.

  The code fragment:

```
    while(TRUE){
        setpr(myid, HIGH_PRIORITY);
        sleep(0);
        DoHeavyComputation();
        setpr(myid, LOW_PRIORITY);
    }
```

is unlikely to cause queued signals, but it steals processor time from other high-priority processes. The next code fragment:

```
while(TRUE){
    setpr(myid, HIGH_PRIORITY);
    sleep(0);
    setpr(myid, LOW_PRIORITY);
    DoHeavyComputation( );
}
```

is more likely to cause queued signals, but has nearly no effect on high-priority processes. It will cause queued signals if LOW_PRIORITY is low enough to let several signals arrive between this process' time slices. The longer the computation and the lower the priority, the more likely signal queuing becomes. Generally, it is better to keep priorities high only around the sleep, and set the background priority of the process high enough to handle its work load with at least a few ticks of sleep time as padding.

A programmer can choose to view queued signals in any of three ways:

- They are too expensive and must be avoided.
- They are a nifty communication tool and the cost is fine.
- Signal queuing is a form of graceful degradation which lets designers cut timing tolerances much closer than they could without signal queuing.

The last point needs a little discussion. If the priority of a process like the one that calls DoHeavyComputation( ) is set high enough, signals never queue, but other processes with even more crucial tasks might be degraded. If its priority is set low enough, the computation will take longer than the inter-signal time and the signal queue will grow until it uses all of memory. In the middle ground are a range of priorities that cause signals to queue occasionally. For instance, a priority of 200 might cause a queued signal every ten minutes and a priority of 202 might cause a queued signal every four hours. The designer can balance the cost of a queued signal against the cost of various priority arrangements.

8.9.1 Performance

Here I need to emphasize that this book is not Microware documentation, and details of OS-9 in this book are not specifications. This section involves kernel implementation details of signal processing. These facts are important for the most demanding applications, but they are also subject to change as we find better ways to do things.

If you don't find something in a manual, it isn't "official." Future releases of OS-9 might make the tricks in this book official, or they might stop working. It would be good policy to look carefully at tricks after each kernel upgrade.

One trick is officially documented: OS-9 calls the intercept routine repeatedly until the end of the process' time slice or until the signal queue is empty. It has a high-performance path for this loop. Combining that with the undocumented fact that OS-9 passes the number of queued signals to the intercept routine gives a program enough information to throw signals on the floor when it chooses.

```
SigTrap(QueueL, signal)
int QueueL, signal;
{
    if(signal == VERYIMPORTANT)
        HandleIt(signal);
    else if(QueueL <=1)
        HandleIt(signal);
    rts();
}
```

The above code uses some judgment. When there are queued signals, it only handles very important signals—all others it throws on the floor. When there is no queue, it handles all signals.[9]

The other trick is entirely undocumented: OS-9 allocates a small block of memory to store each queued signal.[10] For up to eight pending signals per process, it keeps the signal node after the signal is received and reuses it for future queued signals to that process. If there are more than eight empty signal slots when the signal queue is empty, then one surplus signal slot is freed each time a signal is delivered.

Allocating and freeing memory is by far the most undesirable aspect of queued signals. The time to send a queued signal varies according to the structure of free memory, and the memory allocation part of `F$Send` masks interrupts unless the memory is allocated from a process' fragment list. The other costs of queued signals are fairly trivial.[11] An eight-deep queue of signals is either a sign of very serious trouble, or a sign that the designer is using signal queues as a buffering mechanism and signal performance is secondary. For signal queues with fewer than eight pending signals, the first signal at each depth of queuing bears the startup cost for that level, and no

[9]A process could also raise its priority when it sees a signal queue and lower it when the queue length stays at one for a lengthy period.

[10] The process descriptor has room for one non-queued signal. That makes the discussion of queued signals a little confusing. A process with eight pending signals has one in the process descriptor and another seven in structures in a linked list attached to the process descriptor.

[11] Sending a signal that queues but does not require allocation of a new node takes about ten instructions more than sending a signal to a process with an empty signal queue.

F$RTE from queue lengths up to eight does an F$SRtMem. A process can prime its signal queue and save other processes the cost of slower F$Sends.

```
#include <stdio.h>
#define TRUE          1
#define Q_DEPTH       8                  /* 7 queued plus one pending */
#define JUNK_SIG      256

Catcher(QLength, Signal)
int QLength;
short Signal;
{
    /* Normally the program would throw out the priming signals. */
    printf("Signal code: %d. Queue length: %d\n", Signal, QLength);
    fflush(stdout);
    rte();
}


main()
{
    int MyID;
    int i;
    MyID = getpid();
    OS9intercept(Catcher);
    _os_sigmask(1);
    for(i=0; i<Q_DEPTH; ++i)
        kill(MyID, JUNK_SIG);           /* Send signals to self */
    _os_sigmask(–1);
    printf("Ready\n");
    while(TRUE)
        sleep(0);
    exit(0);
}
```

8.10 Special Signals

Wakeup signals and kill signals get special treatment. For all other signals, any special significance of a signal number is a convention defined by the programmer or by non-kernel parts of OS-9. Keyboard abort and keyboard interrupt, for instance, are treated as ordinary signals by the kernel.

Table 8.1: Summary of Signal Attributes

- Signals are queued and delivered in first-in-first-out order.
- Delivery of a signal is complete after the process is placed in the active queue and the intercept routine is called.
- If the target process is active or current, signals consider the process activated.
- If a signal intercept routine is not defined, a signal will kill the recipient process.
- If signals are masked, the call to the intercept routine is deferred. Activation is not deferred.
- If signals are unmasked, the intercept routine is called before the target program is resumed.
- `F$Send` sets the B_WAKEUP bit in P$SigFlg and stores the signal number in P$Signal in the process' process descriptor.
- B_WAKEUP is cleared by a call to a process' intercept routine or before the process returns from a sleep or wait.
- P$Signal is updated to the next queued signal (or 0) before each call to a process' intercept routine.

8.10.1 Wakeup

A wakeup signal does not store a value in P$Signal and it is never queued. Wakeup signals do not call the intercept routine and they do not kill processes that have no intercept routine. Since wakeup signals do not queue, sending them is always fast. If there is already a signal pending for a process, a wakeup signal does nothing.

Wakeup has different effects on F$Sleep, F$Wait and Ev$Wait issued from system state and the same system calls issued from user state. The system-state requests return immediately after clearing B_WAKEUP if the bit is set, while the user-state requests only return immediately if there is a non-zero value in P$Signal. This means that a wakeup signal causes the next system-state wait or sleep to return quickly, but is silently cleared by the user-state SVCs.

This special treatment of wakeup signals by system state requests that move processes out of the active queue is important to device drivers. The persistence of wakeup makes the following sequence work:

```
do
    Is input ready?
        return it
    else
        wait for a signal
forever
```

A signal can arrive any time after input is tested. In particular, it can arrive between the test and the wait. Since even a wakeup signal in that interval causes the wait to return, the driver doesn't need to worry about signals that arrive before the wait.

8.10.2 Kill

A kill signal is not queued, it cannot be ignored, and masking signals has no effect on it. It can only be sent between processes with the same owner or from the super group, group zero, to any process. OS-9 sends kill signals as as it does other signals, except that the S$Kill signal value is replaced with E$PrcAbt in P$Signal, and the recipient process is condemned when the signal is sent. Next time it is scheduled the process will terminate with E$PrcAbt as its return code.

8.10.3 I/O Deadly Signals

Signals between 2 and 31 are given special treatment by the I/O system. Only those signals will interrupt pending I/O; other signals are ignored by I/O code. Deadly signals are a new development which is mainly an extension to SCF's special SIGINT and SIGQUIT signals. The handling of deadly signals is not (and probably will never be) uniform. SCF device drivers look for deadly signals and abort when they are received.

RBF and SBF device drivers ignore deadly signals, but the RBF file manager looks for deadly signals at convenient moments. SBF seems to ignore deadly signals entirely.

Signal numbers 0 through 25 are reserved by Microware. The remaining six deadly signals are available for general use.

8.11 Utility Programs

The following program is useful for experimenting with signals. On the command line, you give it a destination process ID and a signal. It attempts to send the signal to the process.

```
#include <stdio.h>
#include <process.h>
#include <signal.h>
#include <errno.h>
#include <const.h>

main(int argc, char **argv)
{
    signal_code sig;
    process_id pid;

    if(argc <3){
        fprintf(stderr, "%s: needs two args <pid> and <sig>\n", argv[0]);
        exit(1);
    }
    pid = atoi(argv[1]);
    sig = atoi(argv[2]);
    if(pid <=1){
        fprintf(stderr, "Invalid <pid>: %d\n", pid);
        exit(1);
    }
    if((errno = _os_send(pid, sig)) != SUCCESS){
         perror("_os_send");
        exit(errno);
    }
    exit(0);
}
```

It is mostly good for playing with demonstration programs, but it can also send stuck processes a wakeup signal…which sometimes helps.

Chapter 9

Alarms

This chapter discusses the use of alarms for time- or interval-dependent processing.

Alarms initiated from user-state cause OS-9 to send specified signals to processes at selected times or intervals. Alarms from system state cause the OS-9 system process to execute specified routines at the indicated times or intervals. System-state alarms do not simply send signals to the system process because the system process is not sensitive to signals. The action of system-state alarms parallels the user-state execution of signal intercept routines.

9.1 User-State Alarms

Probably the two most important applications of user-state alarms are to provide time-outs for operations that aren't guaranteed to complete in bounded time and to schedule time-dependent activities.

9.1.1 Alarms as Guards

The standard OS-9 file managers do not support I/O operations with time-outs. A read( ) with the option to return either with *n* bytes of data or after *t* seconds, whichever comes first, is crucial for applications like data transfer protocols.[1] Before alarms were available, we coded reads with timeouts like this:

```
for(time = 0 ; time <TIMEOUT / POLL_INTERVAL; ++time){
    if(_gs_rdy(InPath) >= Size)
        if(read(InPath, buffer, Size) == −1)
            /* Handle error */
```

[1] ZModem and kermit are two examples of data transfer protocols that use timed reads.

```
        else
            goto ReadOK;
    sleep(POLL_INTERVAL);
}
/* Deal with timeout */
ReadOK:
```

These polled timeouts forced programmers to balance quick response against wasted processor time. If there was no other process active in the system, polling with no sleep at all was acceptable, but if other activity was likely, polling without delay was too wasteful of CPU resources. Longer sleep intervals make polling less wasteful but increase the time it takes to recognize and read input.

With alarms, polling is no longer necessary. An I/O operation will return to the caller for any of three reasons:

1. The operation completes.
2. An error or end of file condition arises.
3. The process receives a deadly signal.

An alarm can be used to "protect" each operation that might wait in the file system by sending a signal after the maximum time the operation can be permitted to wait. Any deadly signal sent by the alarm signal aborts the process out of an I/O wait or sleep.

A timed fgets() is included in the following demonstration program:

```
#include <stdio.h>
#include <signal.h>
#include <errno.h>
#include <const.h>

#define TIME(t)             (0x80000000 |(int)(t * 256))

#define INTERVAL            5
#define STRINGLEN           256
#define ALARMSIG            SIGINT
char *Timedfgets();
extern void *_glob_data;

void IgnoreSig(signal_code sig)
{
    return;
}
```

```
main()
{
    char string[STRINGLEN];

    *string = '\0';
    _os_intercept(IgnoreSig, _glob_data);

    printf("%d second timed read. Type something: ", INTERVAL);
    fflush(stdout);

    Timedfgets(string, STRINGLEN, stdin, INTERVAL);
    exit(0);
}
```

```
char *Timedfgets(char *string, u_int32 len, FILE *file, u_int32 seconds)
{
    alarm_id AlarmID;
    char *RVal;

    if((errno = _os_alarm_set(&AlarmID, ALARMSIG,
            TIME(seconds))) != SUCCESS){
        perror("Error setting alarm");
        exit(errno);
    }
    RVal = fgets(string, len, file);
    if(*string == '\0')
        printf("\nNo input\n");
    else
        (void)_os_alarm_delete(AlarmID);
    return RVal;
}
```

Timed open(), close(), wait(), _ev_wait(), write(), and so forth are simple modifications of the timed fgets(). Alarms can be used to bound the elapsed time in any system call that sleeps or waits in system state.

Properly, alarms should use some signal greater than 25 and less than SIGDEADLY. The signal numbers through SIGHUP should be avoided because they already have meanings. The signals from SIGHUP$+mbox$1 through SIGDEADLY are (currently) undefined and should all abort an I/O operation. The best choices are 26 through 31. These signals are reserved for non-Microware use.

The Timedfgets() example uses SIGINT as the alarm signal. This is an inelegant choice, but drivers that support the range of deadly signals are not yet widespread, so I chose SIGINT to insure that Timedfgets() works with slightly out-of-date drivers.

Fully-conforming device drivers make all signals less than SIGDEADLY suitable for aborting an I/O operation. Overloading SIGINT by making it mean keyboard interrupt or time-out is not good practice, but it works even with device drivers that don't yet support the *sigdeadly* convention.

A fairly general timed function mechanism can be implemented with this header file (named timed.h):

```
#include <setjmp.h>
#include <signal.h>
#include <errno.h>

#define ALARMSIG                    SIGINT
#define TIME(t)                     (0x80000000 |(int)(t * 256))
#define TIMED_FUNCTION(timeout)     {int AlarmID; jmp_buf jmp_buffer;\
                                    if(setjmp(jmp_buffer) == 0){\
                                    AlarmID = SetAlarm(jmp_buffer, timeout);

#define IF_TIMEOUT                  ClearAlarm();}else{_os_sigmask(−1);
#define END_TIMED_FUNCTION          ClearAlarm();}}
```

The header file defines three macros: TIMED_FUNCTION, IF_TIMEOUT, and END_TIMED_FUNCTION, that can be used somewhat like the C-language if-then-else. The macros use the following library of C code:

```
#include <stdio.h>
#include <errno.h>
#include <const.h>
#include "timed.h"

typedef struct CN {
    struct CN *Next;
    int AlarmID;
    void *jmpbuf;
}CatchNode;

extern void *_glob_data;
static CatchNode *TOS = NULL;

/*
    Prototypes
*/
void SigCatch(signal_code);
alarm_id SetAlarm(void *, u_int32);
void ClearAlarm(void);
void SigCatch(signal_code sig)
{
    if((void *)TOS != NULL && sig == ALARMSIG){
        int Alarm;
        Alarm = TOS→AlarmID;      /*Hang onto alarm handle */
        TOS→AlarmID = −1;          /*Alarm doesn't need deleting */
        _os_sigreset( );
        longjmp(TOS→jmpbuf, Alarm);
    }
}

alarm_id SetAlarm(void *buffer, u_int32 Time)
{
    alarm_id Alarm;
    CatchNode *NewNode;

     if((errno = _os_alarm_set(&Alarm,
            (u_int32)(ALARMSIG, 0x080000000 |Time))) != SUCCESS){
        perror("setting alarm");
        exit(errno);
    }

    if((NewNode = (CatchNode *)malloc(sizeof(CatchNode))) == NULL){
        perror("Out of memory in SetAlarm( )");
        exit(errno);
    }
    NewNode→Next = TOS;
    NewNode→AlarmID = Alarm;
    NewNode→jmpbuf = buffer;
    TOS = NewNode;
    return Alarm;
}


void ClearAlarm( )
{
    CatchNode *ptr;
    if(TOS == NULL) return;
    if(TOS→AlarmID != −1)
        (void)_os_alarm_delete(TOS→AlarmID);
    ptr = TOS;
    TOS = ptr→Next;
    free(ptr);
}
```

The following tiny program illustrates use of the timed-code macro package. It uses the timed-code macros to build a timed fgets( ) function call.

```
#include "timed.h"
extern void *_glob_data;
main()
{
    char string[16];
    void *RVal;
    _os_intercept(SigCatch, _glob_data);
    printf("ready for timed input: ");
    fflush(stdout);

    TIMED_FUNCTION(256*5)
        RVal = fgets(string, 16, stdin);
    IF_TIMEOUT
        printf("No input\n");
        fflush(stdout);
        RVal = 0;
    END_TIMED_FUNCTION
    exit(RVal);
}
```

A problem with the preceding set of macros and library functions is that the macros define variables. Since C doesn't let macros define a scope for names, the names in the macro must be unique in each function that calls them. This restriction prevents nested timeouts and only permits one block of code per function to be guarded with a timeout. Passing the variable names, or even a prefix for variable names, to the macros would make them more flexible but a little harder to use.

The general timeout mechanism suggests an unusual application of timed functions. Operations that interact with other processes or with hardware are expected to need timeout protection, but strictly computational problems also may have widely variable response depending on their input data.

A real-time designer might be willing to budget up to 50 milliseconds to compute an exact value to control some physical process. The designer calculates that the computation may take as little as 10 milliseconds or as much as 100 milliseconds depending on the input data. One option is to instrument the computation so it notices when its allotted time expires and returns some sort of error. This technique, however, adds overhead to the function as it constantly checks for timeout. More typical is to look for a less accurate computation that was guaranteed to complete on time. A timed computation offers a third alternative.

```
TIMED_FUNCTION(timeout)
    HeavyComputation();
```

```
IF_TIMEOUT
    UseQuickSolution();
END_TIMED_FUNCTION
```

9.1.2 Alarms as Tickers for Threads

Yet another application of alarms is a primitive version of time-sliced threads within a process that can be implemented with simple C code.

```
/*
    Threads
    Threads takes no arguments. It just runs a demo of simple time-sliced
    threads and quits after running for a while.
    Compile threads.c without any special parameters: cc threads.c
*/
#include <stdio.h>
#include <errno.h>
#include <signal.h>
#include <const.h>
#define TICKRATE          (0x080000000 |20)     /*about .1 seconds */
#define TICKSIG           256


typedef struct TN {
    struct TN *Next;
    void (*ThreadCode)();
}ThreadNode;



/*
    Prototypes
*/
void *MakeThread(void (*)());
void Dispatcher(signal_code);
void KillThread(ThreadNode *);
void Thread1(void);
void Thread2(void);
void Thread3(void);

static ThreadNode First = {&First, NULL};
static ThreadNode *Head = &First;
static alarm_id TickAlarm;
extern void *_glob_data;
```

```
/*
   This function calls the threads in the ThreadNode list in rotation. The
   threads are represented by pointers to functions.
*/

void Dispatcher(signal_code sig)
{
   if(Head→Next != Head && sig == TICKSIG){
      ThreadNode *This;
      This = Head;                                          /*Next thread */
      Head = This→Next;                           /*pre-select for next time */
      if(Head→ThreadCode == NULL)                 /*Bump over dummy node */
         Head = Head→Next;
      _os_sigmask(−1);                                   /*Unmask signals */
      (*This→ThreadCode)( );
   }
}


/*
   Add a node to the ThreadNode list. If it is the only node in the list
   start the ticker alarm.
*/

void *MakeThread(void (*ptr)( ))
{
   ThreadNode *NewNode;

   if(Head→Next == Head)                                   /*First thread */
       if((errno = _os_alarm_cycle(&TickAlarm,
             TICKSIG, TICKRATE)) != SUCCESS){
         perror("Thread ticker alarm failure");
         exit(errno);
      }

   if((NewNode = (ThreadNode *)malloc(sizeof(ThreadNode))) == NULL){
      perror("Out of memory in MakeThread");
      exit(errno);
   }

   /*Make this the next thread */
   NewNode→Next = Head→Next;
   NewNode→ThreadCode = ptr;
   Head→Next = NewNode;
   Head = NewNode;
```

```
    return NewNode;
}


/*
    Remove a node from the ThreadNode list. If there are no threads left
    in the list, delete the ticker alarm.
*/
void KillThread(ThreadNode *id)
{
    register ThreadNode *ptr, *trailer;
    for(trailer = &First, ptr = First.Next; ptr != &First;
            trailer = ptr, ptr = ptr→Next)
        if(ptr == id){
            trailer→Next = ptr→Next;
            if(Head == ptr)
                Head = ptr→Next;
            free(ptr);
            if(trailer→Next == trailer)                    /*If no threads are left */
                _os_alarm_delete(TickAlarm);                    /*turn off the tick */
        }
}


/*
    The thread functions. This program uses separate code for each thread,
    but they could share code.
    Since the threads could theoretically interrupt each other, they are coded
    async-safe.
*/

void Thread1()
{
    u_int32 length=1;
    _os_write(1,"1",&length);
}
void Thread2()
{
    u_int32 length=1;
    _os_write(1,"2",&length);
}
void Thread3()
{
    u_int32 length=1;
    _os_write(1,"3",&length);
}
```

```
main()
{
    void *T1, *T2, *T3;
    u_int32 ticks, delay;

    (void)_os_intercept(Dispatcher,_glob_data);
    T1 = MakeThread(Thread1);                              /*Start a thread */
    T2 = MakeThread(Thread2);                              /*Start a thread */
    T3 = MakeThread(Thread3);                              /*Start a thread */
    for(ticks = 0 ; ticks <200 ; ++ticks){       /*Let the threads run a while */
        delay = 0;
        _os9_sleep(&delay);
    }
    KillThread(T1);                                        /*Kill one thread */
    for(ticks = 0 ; ticks <100 ; ++ticks){               /*See what happens */
        delay = 0;
        _os9_sleep(&delay);
    }
    KillThread(T2);                                    /*Kill another thread */
    for(ticks = 0 ; ticks <100 ; ++ticks){
        delay = 0;
        _os9_sleep(&delay);
    }
    KillThread(T3);                              /*Now all the threads are dead */
    delay = 10;
    _os9_sleep(&delay);
    T1 = MakeThread(Thread1);                                /*Start up again */
    for(ticks = 0 ; ticks <20 ; ++ticks){
        delay = 0;
        _os9_sleep(&delay);                                  /*And shut down */
    }
    KillThread(T1);
    delay = 10;
    _os9_sleep(&delay);
    exit(0);
}
```

With much extra work, similar techniques can be used to implement a fully-functional multithreaded environment. One difference between the primitive threads implemented here and "real" threads is that real threads require the run time library to support multiple stacks. The above example uses one stack for all the threads.

Consequently, it gets into serious trouble unless the threads use only a fraction of the available processor time.

9.1.3 Alarms As Timers

The most conventional use of alarms is to trigger activities at set times or intervals. A text editor might protect its users against serious data loss caused by power failure or other crashes, by using an alarm to write its buffer to disk every minute. Other programs with long expected running times can similarly checkpoint their data to disk. This was a standard trick for super-computer programs that often ran longer than the computer would stay up. Embedded programs often run, approximately, forever. Like those old super computer programs, they should expect the computer to go down for some reason before they complete. Embedded programs with some form of non-volatile storage could use a timer to cause their latest data to be saved into the non-volatile storage.

The classic demonstration function for alarms is the clock program. The clock program calls for an alarm every minute and sleeps. Each time it is awakened the clock program updates the clock's hands and sleeps again. The clock program could become an alarm clock by setting an additional alarm that causes the program to beep.

Alarms set for a particular date and time can do things like initiate backup operations, turn on lights, adjust thermostats, activate security systems, activate a VCR, or switch a computer into or out of daylight savings time.

9.2 System State Alarms

Programmers who dig around in OS-9 writing drivers, file managers, and kernel enhancements have long and enthusiastically wished to add code to the clock driver. There are many nifty things you could do if you could execute time-dependent operations without sleeping or polling the tick counter. Microware recommends against hooking things to the clock interrupt or adding to the clock driver; they see problems with the context for user code attached to the clock (like how much stack space was available), but that hasn't stopped everyone.

System-state alarms constitute an official, "front door" way to write time-dependent system code.

9.2.1 Drivers

Drivers sometimes need to turn disk drive motors off. They want to do that after the drive has been inactive for 15 seconds or so. But, when a drive has been inactive for 15 seconds, control is not in the driver. If it was, the device would no longer be inactive.

If the the driver sets a system-state alarm to go off 15 seconds after each operation finishes and clears the alarm before each operation, the alarm's target routine will be called after 15 seconds of inactivity.

From a device driver, alarms can protect low-level I/O requests. The normal form for the request launches an I/O operation and then waits for an interrupt. With alarm protection the driver can launch the operation without concern that the device might not respond.

To insure that it notices when a disk is replaced with a different disk RBF reads sector zero each time it opens a file. Drivers can improve performance by keeping sector zero in a special buffer and returning that buffer each time the sector is read, but this makes RBF's checking ineffective for drives with removable media. If the driver invalidates its sector-zero buffer every half second, it stands a good chance of catching disk changes, and might save a few reads. Longer intervals give better performance, but might miss disk changes. Invalidating the sector zero buffer after a second of disk inactivity would only miss a disk change that took less than a second. Since head-unload time is generally more than half a second, that technique should be safe and give good performance when the disk is busy.

9.2.2 File Managers

It would be interesting, and probably good, to add system-state alarms to all disk file managers (i.e., RBF and PCF). It would definitely make PCF safer, and it might make RBF faster. Consider PCF, which is descended from the ***pcfm*** file manager found in appendix C. PCF keeps the disk's allocation map (the FAT) in a buffer and only writes it to disk during open and close operations. As files are created and extended, the copy of the FAT in RAM is updated. If the system were to crash, the FAT might not match the data written on the disk and additions to files that were open when the system crashed would be lost. The PCF directory entries, which contain the equivalent of RBF file descriptors, are also kept in RAM until the file is closed. This keeps them from indicating a file longer than the FAT can find, but it is another chunk of data that is lost if the system crashes.

The reliability of PCF could be improved by adding a system-state alarm to each path. The alarm would be initialized as part of the `I$Open` processing for each path with write capability, and deleted as part of `I$Close`. It would attach to a routine that would write the directory entry for the file and the FAT to disk.

This would give PCF the disconcerting tendency to flash the disk light every 15 seconds or so, but it would decrease the data loss in case of a system crash.

PCF's open function would call an assembly language function to set up the alarms. The function would go something like this:

```
            *
            * SetupAlarm(pd, ProcDesc)
            * called from Open and Create when a path is opened for write.
            SetupAlarm:
01c4 48e7           movem.l d1–d3/a0,–(sp)
            * sysglobs will be a6
            * the alarm routine will actually only get d0–d7/a0–a3,
            * and it doesn't need nearly that much.
01c8=4fef           lea.l   –R$Size(sp),sp    make space for register image
01cc 48d7           movem.l d0–d1,(sp)
01d0 41fa           lea.l   DoAlarm(pc),a0
01d4=2f48           move.l  a0,R$pc(sp)
01d8 204f           move.l  sp,a0             a0 for call to a$cycle
01da 4280           clr.l   d0
01dc=323c           move.w  #A$Cycle,d1
01e0 4282           clr.l   d2
01e2 263c           move.l  #$80000000+(256*15),d3 Alarm interval 15 sec
01e8=4e40           os9     F$Alarm           Ignore errors
01ec=4fef           lea.l   R$Size(sp),sp     Clear stack
01f0 4cdf           movem.l (sp)+,d1–d3/a0
01f4 4e75           rts

            * DoAlarm
            * Called with d0 = pathd
            *               d1 = procd
            *               a4 = system procd
            *               a5 = register image
            *               a6 = sysglobs
            * Calls C function AlarmFlush()
            DoAlarm:
01f6 48e7           movem.l a4/a5,–(sp) save the registers we have to preserve
01fa 48e7           movem.l d1/a4/a6,–(sp) set up for call
01fe 220d           move.l  a5,d1 regs
0200=6100           bsr     AlarmFlush (pd, regs, ProcDesc, SysProcDesc, SysGlobs)
0204 508f           addq.l  #12,sp
0206 4cdf           movem.l (sp)+,a4/a5
020a 4e75           rts
```

There is an important inconsistency in register handling by system-state alarms. The system calls that start alarms want a complete 48-byte register packet, but they only use the data registers, the first four address registers, and the PC. A pointer to the entire register structure is passed to the alarm service routine, but the values are not placed in registers. Furthermore, the alarm service routine must return with the values in registers A4 through A6 unchanged.

The code executed by system state alarms must not do anything that could cause the system process to wait, so we cannot initiate a disk-write operation to flush the

FAT and the FD from AlarmFlush( ). We could use a system-state process to do the writes and release it with a signal or event from AlarmFlush( ), or we could set a bit in the path descriptor instructing the next operation on the path to clean the FAT and FD.

PCF uses a write-through scheme for writes of less than a sector. This means that each I$Write of one byte results in a write of one sector to the disk. It would be much faster to write the sector just before reading another sector to take its place in the path buffer or when the path is closed, but that would leave PCF with another type of lost data if the power goes off. Like the FAT and FD, the path buffer could be flushed periodically under the control of an alarm.

9.2.3 System Calls

The most obvious reason to use alarms in system calls is to provide new SVCs that do for events what alarms do for signals. They probably aren't part of OS-9 because events are so much more flexible than signals that timed events would be too complex. Furthermore, it is easy to implement specific timed event functions using alarms.

Here is a new system call that pulses an event:

F$EvTick

Input

d0.l event ID number

d1.l Pulse interval in seconds/*256*

d2.l event pulse value

Output The alarm id in DO.

Errors The F$Alarm error set.

Function F$EvTick pulses an event under the control of an alarm. It functions like Ev$Pulse except that it does not have the option to activate all processes waiting for the pulsed value.

```
                     nam    evtick
                     ttl    Test version of OS9P2
                     use    <oskdefs.d>
                     opt    –l
                     psect  os9p2,(Systm<<8)+Objct,((ReEnt+SupStat)<<8)+1,1,256,Entry

000000f0  F$EvTick   equ    $f0

     *
     * Startup for os9p2 called during system coldstart
     * a3 Global data pointer for os9p2
```

```
               * a6 System global data pointer
               *
               * Return:
               * with carry clear.  Otherwise startup will abort
               *
0000 43fa  Entry      lea     SvcTbl(pc),a1
0004=4e40             os9     F$SSvc
0008 4e75             rts                       return (carry as set from F$SSvc)

000a 00f0  SvcTbl     dc.w    F$EvTick
000c 0002             dc.w    EvTickCod−*−2 offset to code
000e ffff             dc.w    −1                end of table

               * Input
               *          d0.l Event ID number
               *          d1.l Pulse interval
               *          d2.l Event pulse value
               * Output d0.l Alarm ID
               * Error:  A$Cycle errors
               *          d1 Error code
               EvTickCod
               *
               * Make stack image
               *
0010=4fef             lea.l   −R$Size(sp),sp    Make space for register image
               *
               * prepare register image for EvPulse system call
               *
0014=2f40             move.l  d0,R$d0(sp)       Save event ID number
0018=7000             moveq.l #Ev$Pulse,d0
001a=2f40             move.l  d0,R$d1(sp)       Set Ev$Pulse function code
001e=2f42             move.l  d2,R$d2(sp)       Save event pulse value
0022 41fa             lea.l   Pulser(pc),a0     Address of alarm action
0026=2f48             move.l  a0,R$pc(sp)
               *
               * Setup for A$Cycle call
               *
002a 2601             move.l  d1,d3             Move timer interval from d1 to d3
002c 7000             moveq.l #0,d0
002e=323c             move.w  #A$Cycle,d1
0032 2400             move.l  d0,d2
0034 08c3             bset    #31,d3            Turn on high bit to indicate sec/256
0038 204f             move.l  sp,a0             Point a0 at register image
003a=4e40             os9     F$Alarm
003e=48ed             movem.l d0,R$d0(a5)       Don't change cc
0044=4fef             lea.l   R$Size(sp),sp     Clear stack
0048 4e75             rts                       Return with carry from F$Alarm
               *
               * Called by the system state alarm.
```

```
              *
004a=4e40 Pulser     os9     F$Event
004e 4e75            rts
00000050             ends
```

To test the new F$EvTick system call from a C program we need new function to provide a C binding for the SVC:

```
                     nam     TstTick
                     ttl     Test EvTick system call
                     use     <oskdefs.d>
                     opt     –l
000000f0  F$EvTick   equ     $f0
                     psect   TstTick,0,0,0,200,0
              *
              * EvTick(event, interval, pulse_value)
              *
0000 2f02  EvTick:   move.l  d2,–(sp)
0002 242f            move.l  8(sp),d2
0006 4e40            os9     F$EvTick
000a 6504            bcs.b   EvErr
000c 241f  EvXt      move.l  (sp)+,d2
000e 4e75            rts
0010 7000 EvErr      moveq   #0,d0
0012=2d41            move.l  d1,errno(a6)
0016 60f4            bra.b   EvXt
00000018             ends
```

The following C program tests and demonstrates the new F$EvTick SVC. It sets up a ticking event and waits for the event 40 times. For each tick the program prints a dot. After 40 ticks it cleans up and exits.

```
#include <stdio.h>
#include <events.h>
#include <alarm.h>
#include <ctype.h>
#include <errno.h>
#include <const.h>

#define TRUE   1
#define FALSE  0
#define PULSE  10
```

```
/*
    testtick:
            Usage: testtick wait_event

    This program links to one event, Wait_Event, and starts the event
    ticker for that event. After a few dozen ticks it deletes the alarm.
*/

char *Wait_EName=NULL;

event_id Wait_Event;
int Wait_val=PULSE;
char *Called_Name;

/*
    Prototypes
*/
extern alarm_id EvTick(event_id, u_int32, int32);
void Process_Parms(int, char **);
void Link_To_Event(void);

main(int argc, char **argv)
{
    int ct;
    alarm_id AlarmID;

    Called_Name = argv[0];
    stdout->_flag |= _UNBUF;                /* Unbuffered output */
    Process_Parms(argc, argv);
    Link_To_Event( );
    if((AlarmID = EvTick(Wait_Event, 350, PULSE)) == 0){
        perror("_os_ev_tick failed");
        exit(errno);
    }

    for(ct=0 ; ct <40; ++ct){
        if((errno = _os9_ev_wait(Wait_Event, &Wait_val,
                Wait_val, Wait_val)) != SUCCESS){            /*error */
            perror("Failure in ev_wait");
            exit(errno);
        }
        putchar('.');
    }
    if((errno = _os_alarm_delete(AlarmID)) != SUCCESS){
        perror("_os_alarm_delete failed");
        exit(errno);
    }
    (void)_os_ev_unlink(Wait_Event);

    exit(0);
}


void Process_Parms(int argc, char **argv)
{
    register int ptr;

    if(argc != 2){
        fprintf(stderr, "%s: needs an event name\n", Called_Name);
        exit(1);
    }

    Wait_EName = argv[1];
}


void Link_To_Event()
{
    if((errno = _os_ev_link(Wait_EName, &Wait_Event)) != SUCCESS){
        perror("Failure in ev_link");
        exit(errno);
    }
}
```

To test the new system call, compile and assemble the programs:

```
r68 evtick.a –o=os9p2.r
l68 os9p2.r –l=/h0/lib/sys.l –o=os9p2
r68 tsttick.a –o=tsttick.r
r68 evwait.a –o=evwait.r
cc testtick.c tsttick.r evwait.r –f=testtick
```

then create a new boot file on a floppy:

- Copy your bootlist.d0 file into bootlist.d0.test.
- If you don't already have a placeholder os9p2 in your init module, add os9p2 to the customization module list in the init module.

- run “os9gen –z=bootlist.d0.test –e /d0” (replacing d0 with some other mountable disk drive name if your usual floppy boot is not on /d0).
- Reboot your system from /d0.

or on a tape. If your normal boot tape generation procedure looks something like this:

```
merge –z=bootlist.test > −testboot
fixmod –uo=0.0 testboot
tapegen –b=testboot "–v=test boot" –t=Mycroft
```

- If you don’t already have a placeholder os9p2 in the init module, add os9p2 to the customization module list in the init module and make a new boot master file—testboot in the example.
- merge testboot and os9p2 into a new temporary master bootfile.
- ***tapegen*** from the temporary master.
- Reboot your system from the tape.

You can now create a new event with ***evcreate***,

```
$ evcreate test
```

and test the ticker:

```
$ testtick test
```

Testtick writes a period to the screen a bit less than once per second for a while, then it removes the alarm and goes away.

9.2.4 System Processes

In many cases, a system process can execute periodically either by using timed sleeps or alarms. If a system process is *only* concerned with periodic execution, timed sleeps are generally a better tool than alarms. If the process wants to execute non time-driven code *and* time-driven code at the same time, or wait for either a time interval or some other event, alarms are the best tool.

The following example of a system-state process using alarms stretches the point a little. It uses a wait() to pause until its child process terminates, and alarms make it run periodically while it waits. It could be redesigned to use some other method than wait() to detect termination of its child, but wait() plus alarms was easy to do and it makes a good example program.

The following system-state process is called ***profiler***. It runs another process and creates a module that gives some sort of statistical notion of the execution profile of the child process.[2]

Profiler creates a data module twice the size of the executable part of the primary module of the monitored process. A system-state alarm hits every clock tick. The code executed by the alarm uses the offset of the child process' PC in its module as an array subscript into an array of 32-bit counters in the data module and increments the counter.

When ***profiler*** terminates, the data module can be saved or analyzed in memory. ***Dump*** is an adequate analysis tool, but ***Analyse*** is slightly better. Much more useful analysis programs should be easy to write. The nicest tools would use the .stb module for the monitored module to relate PC values to symbolic names.

```
#include <types.h>
#include <stdio.h>
#include <module.h>
#include <process.h>
#include <errno.h>
#include <signal.h>
#include <const.h>
#include <machine/reg.h>
#include <setsys.h>

/*
   Usage:
      profiler <module> <args> <redirection>
   Creates a data module named profiler.data twice the size of the main module of
   the monitored process. The data module is treated as an array of unsigned longs.
   Profiler uses system state alm_cycle to cause its monitor routine to be called on each
   tick. Then it forks the module with args and waits for it to complete. Each time
   the monitor routine is awakened, it increments the array entry corresponding to
   its offset from the beginning of the main module.

   The module to be monitored must already be in memory.
*/
#define TRUE              1
#define HEADER_SIZE       72
#define CRC_SIZE          3

unsigned long *counters;
unsigned char *progcode;
unsigned ProgSize;
```

[2] ***profiler*** must be run by the super user.

```
Mh_exec datamodule;
Mh_exec progModule;

extern char **_environ;
void *procDesc=NULL;

/*
    Prototypes
*/
void InitRegs(REGISTERS *, process_id);
alarm_id CyclicAlarm(REGISTERS *);
void Init(char *);
int MakeDM(char *, int);

int Monitor( );

void InitRegs(REGISTERS *regs, process_id pid)
{
    regs→d[0] = (u_int32)pid;
    regs→d[1] = (u_int32)progcode;
    regs→d[3] = ProgSize;
    regs→a[2] = counters;
    regs→a[3] = &procDesc;
    regs→pc = (u_int32)Monitor;
}


main(int argc, char **argv)
{
    process_id pid;
    process_id this_pid;
    alarm_id AlarmID;
    status_code status;
    REGISTERS RegSet;

    if(argc <2)
        exit(1);

    Init((char *)argv[1]);
    /*
        keep the pid in d0
        the primary module body pointer in d1
        the program size in d3
        the proc desc pointer pointer in a3
        the counters pointer in a2

        The alarm service routine:
            compares current proc to d0
            if != it returns
            Gets proc→pc into d2
            Calculates d2 = (d2 −code_start) The answer will be even.
            Doubles d2
            increments 0(d2,a2)
            returns
    */
    if((errno= _os_exec(_os_fork, 0, 3, argv[1], argv + 1, _environ, 0, &pid,
            mktypelang(MT_PROGRAM, ML_OBJECT), 0)) != SUCCESS){
        perror(argv[1]);
        exit(errno);
    }

    InitRegs(&RegSet, pid);
    if((AlarmID = CyclicAlarm(&RegSet)) == 0){
        _os_send(pid, SIGKILL);
        perror("Error initializing the alarm");
        exit(errno);
    }

    do{
        errno = _os_wait(&this_pid, &status);
    }while(pid != this_pid);

    if(status != 0)
        fprintf(stderr, "%s terminated with status %d\n",
            argv[1], status);
    (void)_os_alarm_delete(AlarmID);
    exit(0);
}


/*
    Init links to ModName and creates a data module with a data area twice the
    size of the the non-header area of modName.
    Initialize progModule, counters, progcode, ProgSize
*/
void Init(char *ModName)
{
    char dmName[64];
    u_int16 type_lang=0, attr_rev;
    Pr_desc prc = sysglob(Pr_desc, D_Proc);

    /*
        Set up required for system processes written in C.
    */
    stdin->_fd = prc->_path[0];
    _from_new(stdin);
    stdout->_fd = prc->_path[1];
    _from_new(stdout);
    stderr->_fd = prc->_path[2];
    _from_new(stderr);
    /*
        Keep the OS from closing these paths on exit.
        The C runtime will close them.
    */
    prc->_path[0] = 0;
    prc->_path[1] = 0;
    prc->_path[2] = 0;

    if((errno = _os_link(&ModName, (Mh_com *)&progModule,
            (void **)&progcode,
            &type_lang, &attr_rev)) != SUCCESS){
        perror(ModName);
        exit(errno);
    }

    ProgSize = progModule->_mh._msize -(HEADER_SIZE + CRC_SIZE);
    strcpy(dmName, ModName);
    strcat(dmName, "_prof");
    if(MakeDM(dmName, ProgSize * 2) != 0){
        perror(dmName);
        exit(errno);
    }
}


        _asm("
                use      <oskdefs.d>
        _sysattr: equ    ((ReEnt|SupStat)<<8)|1
        DMAttr  equ      (ReEnt<<8)+1
        DMTyLn  equ      (Data<<8)+0
        MakeDM: movem.l d1-d4/a0-a2,-(sp)
                         link           a5,#0
                move.l   d0,a0          Module name string
                move.l   d1,d0          Module size
                move.w   #DMAttr,d1     Attr/rev
```

```
          move.w  #Updat_+PRead_,d2 Permissions
          move.w  #DMTyLn,d3     Type/Lang
          moveq.l #0,d4          any color
          os9     F$DatMod
          bcs.b   MakeDMEr
          move.l  a2,datamodule(a6) Data module pointer
          move.l  a1,counters(a6)   Counter's array
          moveq.l #0,d0          Good return
MakDMX    unlk    a5
          movem.l (sp)+,d1-d4/a0-a2
          rts
MakeDMEr  moveq   #0,d0          Sweep register
          move.w  d1,d0          error code
          move.l  d0,errno(a6)
          bra.b   MakDMX

          * CyclicAlarm(regs)
CyclicAlarm: movem.l d1-d4/a0,−(sp)
          link    a5,#0
          move.l  d0,a0          register image
          moveq.l #0,d0
          move.w  #A$Cycle,d1    Function code
          move.l  d0,d2          must be zero
          moveq.l #1,d3          Time interval
          os9     F$Alarm
          bcs.b   CAErr
          * alarm id is in d0
CAEx      unlk    a5
          movem.l (sp)+,d1-d4/a0
          rts
CAErr     moveq   #0,d0          sweep register
          move.w  d1,d0          move error code
          move.l  d0,errno(a6)
          moveq.l #0,d0
          bra.b   CAEx

          *
          *       d0 = pid
          *       d1 = program code start
          *       d3 = program code size
          *       a2 = address of counters
          *       a3 = pointer to pointer to process desc (or pointer to 0)
          *
Monitor:  tst.l   (a3)           Is proc desc ptr set yet?
          bne.b   MProcOK        yes: use it
          move.l  D_PrcDBT(a6),a0
          os9     F$FindPD       get pointer to proc desc in a1
          move.l  a1,(a3)
MProcOK
```

```
                move.l  (a3),a1
                * now process desc ptr is in a1
                move.l  P$sp(a1),a0     proc's stack pointer
                move.l  R$pc(a0),d2     Process's PC
                sub.l   d1,d2           PC - prog_start
                bcs.b   MonX            Before the prog area
                cmp.l   d2,d3           Out of range?
                bls.b   MonX            Yes; ignore
                lsl.l   #1,d2           Multiply offset by two
                addq.l  #1,(a2,d2)      Increment counter[word_number]
        MonX    rts
");
```

I chose to write large parts of ***profiler*** in assembly language because I find it easier to understand the exact behavior of assembly language than C for some of the manipulation done in ***profiler***. I think the entire program could have been written in C.

The alarm routine, Monitor, takes advantage of OS-9's careful treatment of registers. Monitor saves no registers; this feels dangerous, but in this case it is correct.

9.3 Programs

The following program is a trivial analysis program for the data module produced by ***profiler***.

```
#include <stdio.h>
#include <module.h>
#include <errno.h>
#include <const.h>

#define HEADER_SIZE         72              /*same value profiler uses */
#define CRC_SIZE            3

/*
   Analysis should be called with the name of the data module it should
   analyse.
*/
main(int argc, char **argv)
{
   u_int32 *array;
   int i;
   u_int32 ArraySize;
   u_int32 MaxVal=0;
   int MaxIdx;
```

```
    mh_com *modPtr;
    u_int16 TypeLang=0, AttrRev;

    if((errno = _os_link(&argv[1], &modPtr, (void **)&array,
            &TypeLang, &AttrRev)) != SUCCESS){
        perror("linking to data module");
        exit(errno);
    }

    ArraySize = ((modPtr->_msize -HEADER_SIZE) -CRC_SIZE -
            (strlen(argv[1]) + 1)) / sizeof(u_int32);
    printf("Visit Table\n");
    printf("%10s\t%10s\n", "Offset", "Count");
    for(i = 0; i <ArraySize; ++i)
        if(array[i] >0){
            printf("%10x %10u\n", (i * 2) + HEADER_SIZE,
                array[i]);
            if(array[i] >MaxVal){
                MaxVal = array[i];
                MaxIdx = i;
            }
        }
    printf("Max count %d at %x\n", MaxVal, (MaxIdx*2) + HEADER_SIZE);

    _os_unlink(modPtr);
    exit(0);
}
```

When I run ***profiler*** on a tiny program named ***eatmpu***,

```
$ analysis eatmpu_prof
```

generates the following output:

```
Visit Table
    Offset       Count
       2aa        1710
       2ac         489
       2b0        9838
       2b2         308
       2b4         409
       2ba        1299
Max count 9838 at 2b0
```

These numbers are more meaningful when I use ***debug*** or ***srcdbg*** to give them a symbolic interpretation:

```
$ debug eatmpu
default symbols belong to 'eatmpu'
dbg: l eatmpu
dbg: di .r7+2aa
main+0x1A     >2004               move.l d4,d0
main+0x1C     >4C060000           mulu.l d6,d0
main+0x20     >2A00               move.l d0,d5
main+0x22     >5284               addq.l #1,d4
main+0x24     >0C8402625A00       cmpi.l #40000000,d4
main+0x2A     >6D00FFEE           blt.w main+0x1A
main+0x2E     >4CED0070FFF4       movem.l -12(a5),d4-d6
main+0x34     >4E5D               unlk a5
main+0x36     >4E75               rts
```

It's not a surprise that the `mulu` in the loop is the most popular instruction.[3]
Srcdbg gives a C interpretation of ***analysis*** output:

```
1.$srcdbg eatmpu
Reading symbol file "eatmpu.dbg".
eatmpu.c
Reading symbol file "eatmpu.stb".
Context: eatmpu\_cstart
SrcDbg: li eatmpu
SrcDbg: dil .r7+0x2aa
   6:       k = i * j;
            ^

main+0x1a      >2004               move.l d4,d0
main+0x1c      >4C060000           mulu.l d6,d0
main+0x20      >2A00               move.l d0,d5
   5:   for(i = 0 ; i < 40000000; ++i)
                                  ^

main+0x22      >5284               addq.l #1,d4
   5:   for(i = 0 ; i < 40000000; ++i)
                    ^

main+0x24      >0C8402625A00       cmpi.l #40000000,d4
main+0x2a      >6D00FFEE           blt.w main+0x1a
main+0x2e      >4CED0070FFF4       movem.l -12(a5),d4-d6
main+0x34      >4E5D               unlk a5
main+0x36      >4E75               rts
SrcDbg(DILIST):
```

[3] When the clock ticks during an instruction, the PC points at the *next* instruction.

Chapter 10

Process Scheduling

OS-9 was originally designed as an operating system for real-time applications, and it hasn't moved far from that heritage. Real-time work required that OS-9 offer fast response. It didn't require a whole range of options for adjusting each process' performance, but Microware included them anyhow. This chapter discusses the way that OS-9 distributes processor time and the control that you have over it.

10.1 A Low-Level View

If you get close enough to the machine, processes disappear. Everything looks like one big program. The microprocessor hums along executing instructions; gets an interrupt and branches to the vector for that interrupt; executes more instructions.... Sometimes it moves the stack pointer around.

If we move back a little bit from the CPU's view of the system, we can see that the processor is running a process for a while, then it runs OS-9 itself, then it either returns to the same process or moves to a different one. The processes are distinguished by the values in the machine registers (the MPU's registers, the FPU's registers, and the state of any memory management hardware that's in use).

When the system clock ticks, it asserts a hardware interrupt. This interrupt causes control to be vectored through the OS-9 kernel to the part of OS-9 responsible for the management of the process queues. The action of this code can be divided into two steps:

1. The kernel checks the queue of sleeping processes. Any processes that are ready to wake up are moved to the active queue.

2. Then it checks the number of ticks during which the current process has been active. If the current process has used its time slice, the process descriptor is inserted in the active queue and the process at the front of the active queue is made the current process.

Each time OS-9 is called on to add a new process to the active queue (for instance, when the current process reaches the end of its time slice), it ages all eligible processes. This aging doesn't actually involve running through the active queue and changing the age of each process. Process age is recorded as an offset from a counter associated with the active queue. The entire queue is aged by incrementing the counter. When the 32-bit counter overflows, the kernel must adjust all the process descriptors in the active queue to reflect the counter's change from $ffffffff to $00000000, but that problem only occurs rarely. It takes more than 10,000 hours of continuous operation to cause the counter to roll.

The current process is the one that OS-9 runs next. There is a pointer to the current process' process descriptor in system global data. A process is made "current" by removing its descriptor from the active queue and putting a pointer to the descriptor in the current process field.

10.2 Aging

Aging eligible processes is the crux of the OS-9 scheduling algorithm. In the simplest case, the scheduler increments the base age of the active queue. This increases the age of each process in the queue that hasn't reached some maximum age. It doesn't change the positions of the processes in the queue relative to one another, but it does alter the position at which a new process will be inserted. When a process is placed in the active queue, its priority is used as its age and the queue is searched for a place to insert the new process so the queue remains sorted by age.

Imagine that there are only two active processes; one with a priority of ten, the other with a priority of one. The high-priority process is inserted at the front of the queue and run until its time slice is up, say four ticks. When the high-priority process returns to the active queue the scheduler increases the age of the other processes in the queue. The low-priority process now has an age of one. The high-priority process with its priority of ten is inserted at the front of the queue and run again immediately. After another time slice of four ticks, the age of the low-priority process becomes two. The high-priority process is inserted before it and run for a third time slice. After the high-priority process has used nine time slices, it enters the queue with the same age as the low-priority process. The high-priority process is inserted at the end of the queue, and the low-priority process runs. It only runs for one time slice because the other process will age to 11 and the low-priority process will go to the end of the queue with an age of one.

There are some important things to note about this time-slicing scheme. High-priority processes run for longer stretches and they run frequently. Low-priority processes don't run long or often, but they do get a share of the processor no matter how busy it is. If all the processes have the same priority, each process runs for one time slice then drops to the end of the queue behind all the aged processes.

Think of the processor as a merry-go-round. You can pay almost any amount you like for a ticket. The more you pay, the more priority you have. Priority works for you in two ways. It helps you get a good position in line. The attendant finds you a place in line where there are no people with lower priorities ahead of you. It may also let you ride longer. You are allowed to stay on the ride until the first person in line has more priority than you.

Now, the merry-go-round operators have a notion of fairness. They hate to see people wait in line, so every time they let someone onto the ride they go through the line and increases the priority on each person's ticket. Even if you purchased the least expensive ticket, eventually it will be worth enough to get you to the front of the line. Once you get on the ride, the priority of your ticket reverts to what you paid for it. The length of your wait in line (your age) no longer counts. If you bought a cheap ticket you probably won't ride for long.

10.3 Adjustments

The aging algorithm, adjusted with priorities, works well for most situations, but special problems need different solutions. There is no way to deactivate OS-9's normal aging algorithm, but some priorities can be made special.

If you want to run a program with the least possible impact on other programs, OS-9 gives you a special trick that prevents the program from running when *any* other process wants the processor. You can't do that by simply assigning the process a low priority—eventually it will age until it reaches the front of the active queue—but you can designate a range of priorities for a low-priority class by adjusting the D_MaxAge field. The D_MaxAge field defines all priorities less than its value as lower priority. Processes with priorities less than D_MaxAge never age to a position in the active queue ahead of a process with a priority greater than D_MaxAge.

Normally D_MaxAge is zero. That's a special value that means "don't use D_MaxAge." It doesn't mean that no process may age beyond zero. All processes on the active queue will be aged. If you write a program (which must be run in superuser mode) that resets D_MaxAge to some other value, D_MaxAge takes effect.

The following code is a skeleton for a program that, for a while, shuts out all processes with lower priorities.

```
#include <stddef.h>
#include <sysglob.h>
#include <process.h>

static u_int16 GetPty(void);

main()
{
    short OldMaxAge, Priority;
    glob_buff SysBuffer;
    /*...  */
    (void)_os_getsys(offsetof(sysglobs, d_maxage), 2, &SysBuffer);
    OldMaxAge = SysBuffer.wrd;
    SysBuffer.wrd = GetPty();
    (void)_os_setsys(offsetof(sysglobs, d_maxage), 2, SysBuffer);
    /*Code to be run with processes at lower priorities locked out  */
    SysBuffer.wrd = OldMaxAge;
    (void)_os_setsys(offsetof(sysglobs, d_maxage), 2, SysBuffer);
    exit(0);
}


static u_int16 GetPty()
{
    process_id tmp;
    u_int16 priority, stmp;
    _os9_id(&tmp, &priority, &stmp, &stmp);
    return priority;
}
```

Since the range of priorities is from 0 to 65535, let's start by dividing the range at 32767. With D_MaxAge equal to 32767, no process will age past that value. If you tend to run most of your work with a priority of 100 or so, your processes will probably never reach D_MaxAge. Your system will run exactly as it did before you altered the value.

If you run a job with a priority of 40000, it will enter the queue with a priority greater than D_MaxAge. None of the processes with priorities less than D_MaxAge run unless the high-priority process signifies that it doesn't want the processor time by waiting or sleeping; i.e., F$Sleep, F$Wait, Ev$Wait, or any of several ways to wait in an I/O operation.

The barrier formed in the range of priority values by D_MaxAge is an effective way to separate processes into low and high priority classes, but it doesn't give high-priority processes exclusive use of the processor. OS-9 continues to schedule processes with priority below D_MaxAge when no process above D_MaxAge is ready to run. When a waiting high-priority process is activated, it immediately replaces any low-priority process as the current process provided that the current process is not in system state. No process can be replaced as the current process when it is in system state, so a high-priority process may have to wait for a low-priority process in system state to return to user state or explicitly relinquish control.

There is another tool for adjusting process scheduling. The D_MinPty field divides processes into classes much more strictly than D_MaxAge. The D_MaxAge value is used to give OS-9 a strong preference for a group of processes. D_MinPty causes OS-9 to completely ignore a group of processes.

All processes with a priority less than D_MinPty are not considered for aging or execution. The scheduler stops scanning the active queue when it gets to a process with a priority lower than D_MinPty, and the dispatcher refuses to run them even if they are at the front of the queue. Processes below D_MinPty continue to hold any system resources (memory, open files, links to modules) that they acquired when they were running, but they don't have access to the processor. Processes with priorities above D_MinPty are aged and run as usual.

D_MinPty is normally set to zero. Since zero is the lowest possible priority, all processes are eligible for aging and execution. If you (a super user) reset D_MinPty to a higher value, any processes below that priority lose their right to run until you set D_MinPty back down again.

You can cause serious trouble by being careless with D_MinPty. If a process set the value of D_MinPty higher than its own priority, the process will finish its time slice and be placed in the active queue *below* D_MinPty. Unless a high-priority program that can set D_MinPty back down or a high-priority shell is running, the system is stuck. D_MinPty remains high and the system is useless until it is rebooted.

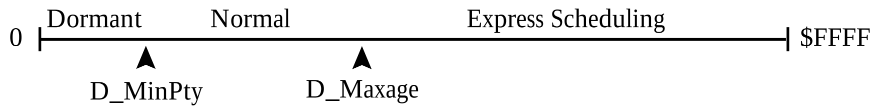
D_MaxAge is used to divide processes into high and low-priority classes. D_MinPty is used to give a process (or group of processes) exclusive use of the processor. Normal applications don't need either of these facilities. Programs that deal with humans need good response time, but they can afford to give up a time slice once in a while. Programs that do real-time control, however, often handle hardware that cares about hundredths or even thousandths of seconds. D_MinPty and D_MaxAge give the programmer tight control over process scheduling that is useful when a time slice interval is significant time.

10.4 Priority Scheduling

Real-time applications often require strict priority scheduling. OS-9's normal process aging algorithm could be serious trouble for such programs, but programs with priorities

Table 10.1: Process Scheduling Summary

Priority Range	Class	Description
0–D_MinPty	Idle	Never executed
D_MinPty–D_MaxAge	Normal	Priority/aging scheduling
D_MaxAge and up	Express	Strict priority scheduling



above D_MaxAge do not age. The range of priorities above D_MaxAge are scheduled strictly according to their priorities. Only lower-priority processes are aged, and they cannot age into the priority scheduling range.

10.5 Preemption

If D_MinPty and D_MaxAge are not set, aging eventually brings every process to the head of the active queue. There, they are given at least a few cycles of processor time, but they are not guaranteed a full time slice or even a full clock tick of processor time. A process that is placed in the active queue either because it is freshly forked or because it has been moved from a sleep, wait, ev_wait, semaphore, or I/O queue, causes a lower-priority current process to be bumped back into the active queue.

If process *x* with priority 50 has aged itself to the front of the active queue and been activated, it might get a full time slice. However, if a process with priority 51 is activated by an interrupt service routine or by interprocess communication from process *x,* process *x* is immediately dumped back into the active queue. The bumped process is treated exactly as if it had used its entire time slice. This is called preemption.

The process that bumped the current process is not automatically made current. It is inserted in the active queue according to its priority and the age of the other processes in the queue. It will be ahead of the preempted process, but may be behind other processes.

Preemption has interesting applications to interprocess communications. If process *x* releases process *y* from a sleep or wait, the effect depends on their relative priorities.

- If the priority of process *x* is greater than or equal to the priority of process *y,* process *x* probably returns from the system call that released process *y.* The system call moves process *y* to the active queue, but it has no effect on process *x.*

- If the priority of process *x* is less than the priority of process *y,* process *x* gives up its time slice just before returning from the system call. It is returned to the active queue and allowed to age to the front of the queue.

10.5.1 System-State Preemption

Processes are only preempted by interrupts or their own actions. No other process gets access to the processor while a process is running, so no other process gets a chance. A process can avoid causing its own preemption by doing no IPC operations and maintaining any locks it has, but the only way to avoid preemption motivated from an interrupt is to be across a scheduling priority barrier from all other processes. Even running in system state is seldom a defense against preemption. The kernelwill preempt a process right in the middle of a system call.

The kernel is preemptable almost all the time, but many file managers are mostly non-preemptable, and all device drivers are non-preemptable. SCF and Pipeman are preemptable. RBF and PCF offer to be preempted occasionally, but often run a hundred or more instructions while preventing preemption. Other file managers are non-preemptable unless they intentionally enable preemption.

When necessary, system-state preemption can be disabled by setting P$Preempt in the current process descriptor to a non-zero value (usually by incrementing it). Incrementing D_Preempt will also disable preemption, but modifying P$Preempt is "the preferred method."

10.6 Tuning for Real-Time Applications

The easy way to handle real-time applications is to use one processor per process. It works. If there is only one active process, you can be certain that no time sharing will take place. Insisting on only one active process at a time isn't as strict a requirement as it seems. A single-user system probably has at most one active process most of the time. If you use ***procs*** to check the state of the processes in a simple workstation, you will find that most of them are waiting or sleeping.

Restricting a real-time system to one active process per processor may be a sad waste of OS-9's power. As soon as a real-time controller has to handle at least two independent ports, it has to use multiprocessing or simulate multiple processors. A simple example is a system that controls the water level in fifty tanks by reading the level in each tank and adjusting its input valve. Checking and adjusting each tank about once every two seconds is easy for a 68000. The neatest way to program the solution is to use fifty processes, one for each tank. Each process sleeps for two seconds, adjusts the valve, and sleeps again. If all the processes woke up and wanted to adjust their tanks at the same time, they would queue up in the active queue. If the delay were too long, a tank might overflow or go dry, but let's assume there is plenty of extra time.

To complicate the problem, let's say that once the computer reads the water level in a tank it must adjust the valve within a very short time. Delaying as much as a hundredth of a second could cause deep trouble. If OS-9's process scheduler is left alone, a process could reach the end of its time slice between the time it reads the level and the time it sends instructions for a valve adjustment. Returning the process to the active queue and leaving it there while other processes run would cause the process to miss the deadline for adjusting the valve. The solution is careful use of D_MaxAge.

Each process must lock all others out of the processor before it reads the water level, and unlock the system after it sends the valve adjustment instructions. If processes tended to have a priority around 256, the sequence might go like this:

1 Set D_MaxAge to 1000.
2 Sleep for 2 seconds.
3 Do setup.
4 Set priority to 2000.
5 Read level.
6 Set valve.
7 Reset priority.
8 Repeat from 2.

Note that the priority is set high at step four. From that step until step seven, the process can not be interrupted by another process.[1]

The only protection on the interval between step one and step four is the duration of a time slice. The definition of the problem allows variable intervals between level checks, so this is not a problem.

OS-9's standard process scheduling algorithm almost always works best if you leave it alone. Under some circumstances you will want to mark off classes of special processes, and in those cases the D_MaxAge and D_MinPty fields alone or in combination can modify OS-9's scheduling behavior. A non-zero value for D_MaxAge gives you two classes of process, both active. D_MinPty gives you two classes with only the high-priority class active.

[1] Process priorities can be used for locking, and sometimes it is the best mechanism. Usually the system can be designed so a locking service like semaphores or events will do the job. This is clearer and seems to be more reliable as the system grows.

Chapter 11

Events

Events are the primary synchronization tool OS-9 offers programmers. Events are wonderfully versatile. This chapter investigates the reasons for events and some of the things that can be done with them.

11.1 A Simple Analogue

Let's start with a parking analogy. This time we'll avoid on-street parking and go to regulated parking lots.

Parking lots sometimes have flimsy little gates on them. Cars approach the gate and follow some protocol, the gate opens, they go through, and the gate closes. I know of a parking lot (in front of the Yale CoOp) where the gates keep track of the number of cars in the lot. If the lot is below capacity, the entry gates open immediately. If the lot is full, they don't open until a car leaves.

I imagine that there is a small computer somewhere in that system. It keeps the number of cars in the parking lot in mind. While the number is below the lot's capacity things are simple. When it reaches capacity things get interesting. The lot is full because many people want to shop. Naturally there are lines of cars waiting at each entry gate—not patiently. The computer would be vehemently despised if it were incorrect or unfair in its handling of the gates.

When a car leaves, the variable that counts the cars in the lot is decremented. Since the number is now below the capacity of the lot, the computer opens an entry gate and lets a car in. When the car passes the gate, the counter is incremented. Now the lot is at capacity again and the entry gates stay closed until another car leaves.

Let me phrase the parking-lot-regulation problem as an algorithm with events.

```
Initialize:
Create an event called Car_Count
with a value of zero, a signal increment of −1
and a wait increment of 1
```

Entry Gate Algorithm:	**Exit Gate Algorithm:**
Link to the Car_Count event	Link to the Car_Count event
When a car arrives	When a car leaves
Ev$Wait on Car_Count for	Let the car out
Min value of 0 and	Ev$Signl Car_Count
Max value of Capacity −1	
Let the car in	

Until the lot is full, Ev$Signl and Ev$Wait just increment and decrement *Car_Count*. When *Car_Count* passes *Capacity* −1, Ev$Wait blocks. All the entry gates get to an Ev$Wait and stop. Ev$Signl never blocks, so cars can always get out of the lot. When a car leaves, the exit gate algorithm does an Ev$Signl which decreases *Car_Count* to *Capacity* −1. One of the waiting entry gates is selected and its Ev$Wait is unblocked. The first thing Ev$Wait does after unblocking is to increment *Car_Count* by one.

If the parking lot system uses events, the entry and exit algorithms are pretty simple. Without the help of events, some nasty problems appear. Actually, they probably won't appear … not immediately. They stay hidden until the worst possible moment, then savage the programmer. The event functions allowed us to confidently say, "One of the waiting entry gates is selected …". It also permits us to increment and decrement *Car_Count* without elaborate precautions.

Picking a gate doesn't seem difficult, nor does arithmetic on *Car_Count*. It's easy to write the entire control algorithm without appealing to system events. The resulting program might go something like this:

```
Initialize:
Create a data module called Car_Count
Set the integer variable in Car_Count to 0
```

	Entry Gate Algorithm	**Exit Gate Algorithm**
1	Link to the Car_Count module	Link to the Car_Count module
2	Call the integer in Car_Count n	Call the integer in Car_Count n
3	When a car arrives	When a car leaves
4	While n >Capacity −1 wait	Let the car out
5	n := n + 1	n := n −1
6	Let the car in	

First let's look at statement 5 in the entry algorithm. To understand how this statement can cause trouble, you have to imagine what the compiler will do with it. It might do the operation with one instruction:

```
addi.l   #1,n(A6)
```

This is safe provided that all the processes are running on the same processor (reasonable). However, the compiler might generate these instructions instead:

```
move.l  n(A6),D0
addq.l  #1,D0
move.l  D0,n(A6)
```

Since the operating system could catch an interrupt and give control to another process in the middle of this string of instructions, we have to see what happens when two processes try to update *n* at the same time.

Entry Gate One	**Entry Gate Two**
move.l n,D0 addq.l #1,D0	
… The clock ticks … and the process for Entry Gate Two starts running	
	... move.l n,D0 addq.l #1,D0 move.l D0,n
… Time passes … and the process for Entry Gate One runs again	
move.l D0,n	

The process for Entry Gate One just wiped out the change Entry Gate Two made to *n* and any other changes to *n* made during the interval marked "Time passes."

This problem with altering shared variables (like *n*) can cause the program to lose count of the number of cars in the lot.

The other problem with the naive parking lot algorithm is that all the entry gates might open at the same time, each thinking it is the only one opening. Imagine that the lot is full and there are lines waiting at five entry gates. A car leaves and *Car_Count*'s counter is decreased to *Capacity* −1. All the entry gates have been busily watching *Car_Count* for that change so they all leave their loops and let a happy driver into the lot. Then they each increment the counter and discover, too late, that there are four cars too many in the lot.

There are ways to avoid these problems. The easiest way is to use events. OS-9 takes care that only one process updates an event's variable at a time: it protects the event's shared variable. It also lets you decide whether to let all the processes waiting on an event go at once or select just one; it can force waiting processes into a queue. The event system in OS-9 takes those two features, a protected shared variable and process queuing, and elaborates on them.

11.2 Some Event-Handling Utilities

It is useful have a list of all the events in your system. The Ev$Info function of the event system is meant for exactly that purpose. The following program uses Ev$Info to produce a directory of active events.

```
/*
    EvDir
    List all events defined to OS–9 together with their properties
*/
#include <stdio.h>
#include <events.h>
#include <errno.h>
#include <const.h>
#define TRUE   1

main()
{
    event Buffer;
    event_id i;

    printf("Event Directory\n ID Name Value W S Links\n");
    for(i=0;TRUE;++i){
        if(_os_ev_info(i, sizeof(Buffer), &Buffer) != SUCCESS)
            break;                    /*end of events */
        printf("%5d %–11s %5d %2d %2d %2d\n",
                Buffer._ev_eid,
                Buffer._ev_name,
                Buffer._ev_value,
                Buffer._ev_winc,
                Buffer._ev_sinc,
                Buffer._ev_link);
    }
    exit(0);
}
```

It's also nice to be able to dispose of an event that is left around in the system.

```
/*
    EvDel
    There isn't a utility command to delete events (yet). This fills that role. Use the
    command: evdel Wait1 to delete the event Wait1. Ev$Delete won't
    delete an event with a non-zero link count, so, if Ev$Delete fails, unlink the
    event until it can be deleted. This a little dangerous. Somewhat like an unlink
    utility that would always unlink a module until it was removed from memory.
*/
#include <stdio.h>
#include <events.h>
#include <errno.h>
#include <const.h>

main(int argc, char **argv)
{
    event_id Event_id;
    char *Event_Name;

    if(argc <2){
        printf("%s usage is:\n %s EventName\n", *argv, *argv);
        exit(1);
    }
    Event_Name = argv[1];
    if((errno = _os_ev_link(Event_Name, &Event_id)) != SUCCESS)
        exit(errno);
    do
        (void)_os_ev_unlink(Event_id);
    while(_os_ev_delete(Event_Name) != SUCCESS);
    exit(0);
}
```

Events are normally created by the programs that use them, but experimenting with events is easier if you can create them to specification without modifying a program each time you want a new event. The following program takes all the parameters for `Ev$Creat` on its command line and issues the `Ev$Creat` for you.

```
/*
    EvCreate
    Create an event. The usage of this command is:
        EvCreate Event_Name Wait_incr Signal_incr Initial_val
    If it is only given an event name, EvCreate will make an event that can be used
    as a semaphore (with Ev$Wait triggering on 0).
*/
#include <stdio.h>
```

```
#include <events.h>
#include <errno.h>
#include <const.h>

#define WAIT      0
#define SIGNAL    1
#define INITIAL   2

main(int argc, char **argv)
{
    char *Event_Name;
    u_int32 Values[3];
    event_id ID;
    int i;

    if(argc <2){
        fprintf(stderr, "%s Usage:\n %s %s\n",
                *argv, *argv,
                "Event_Name [wait_inc signal_inc [initial_value]]");
        exit(1);
    }
    /*
        Set default values
    */
    Values[WAIT] = -1;
    Values[SIGNAL] = 1;
    Values[INITIAL] = -1;
    Event_Name = argv[1];
    for(i=2;i<argc;++i)
        Values[i-2] = atoi(argv[i]);
    if((errno = _os_ev_creat(Values[WAIT], Values[SIGNAL], 0x0555,
            &ID, Event_Name, Values[INITIAL], 0)) != SUCCESS){
        fprintf(stderr, "Ev_Create(%d, %d, %d, %s) gave error %d\n",
                Values[INITIAL], Values[WAIT],
                Values[SIGNAL], Event_Name, errno);
        exit(errno);
    }
    /*
        Unlink the event before exiting to keep the event's link count accurate.
    */
    (void)_os_ev_unlink(ID);
    exit(0);
}
```

11.3 A Semaphore

Limiting the event variable to two states, open and closed, reduces events to a basic process synchronization operation. It comes in several similar flavors, and is usually called a counting semaphore or (on IBM mainframes) an event.

A counting semaphore is designed to manage access to bounded resources, like buffer pools, multi-user hardware, and shared queues and stacks.

Access to a buffer pool with *n* buffers can controlled with a counting semaphore, though the actual distribution of buffers has to be done by another mechanism. A process requests access to the buffer pool with a SemWait() function:

```
boolean SemWait(event_id sem)
{
    int32 value
    _os9_ev_wait(sem, &value, 1, n);
    return (value >0);          /* return false if the wait was ended by a signal */
}
```

This returns immediately until *n* buffers from the pool are consumed. After the buffers are gone SemWait() requests wait.

A process releases a buffer for public use with the SemSignal() function:

```
void SemSignal(event_id sem)
{
    int32 value;
    _os_ev_signal(sem, &value, FALSE);
}
```

For this example the event should be created with

```
Ev$Creat
     initial value: n
     auto-increment for Ev$Wait: −1
     auto-increment for Ev$Signl: 1
Ev$Signl:
    The value of actv_flag only matters when the resource
    is first created
```

Events don't limit the range of the semaphore's values. This is inconvenient because it leaves programs that use semaphores vulnerable to a programming bug. It is impossible to drive the value of the semaphore below zero by doing too may Ev$Wait calls. An Ev$Wait SVC that would reduce the value too far will wait. It is possible to

Ev$Signal the semaphore too many times. A correct program will not do this, but the F$Event service code does not prevent it. The SemSignal() function can detect this error:

```
void SemSignal(event_id sem)
{
    int32 value;
    _os_ev_signal(sem, &value, FALSE);
    if(value >n){
        _os9_ev_wait(sem, &value, 1, 2147483647));
        /* Print an error message */
    }
}
```

The following two programs let you experiment with semaphores:

```
/*
    SyncWait
    This program is a general-purpose tool for experimenting with events. It can use
    either a Wait/Signal or a simple Wait protocol. Its usage is:
            Syncwait Wait_Event [Signal_Event] low [high]
    In its simplest form: SyncWait WaitEvent low, it uses a loop with an Ev$Wait
    in it. Each time it gets through the wait it prints a message with its process
    number and the low bound for the Ev$Wait. Leaving out the high bound for
    the Ev$Wait on the command line tells the program to use the same number
    for low and high bounds.
    If a Signal-event name is given on the command line (with a wait-event name),
    SyncWait uses a Wait/Signal protocol. It adds an Ev$Signl to the loop, which
    now goes:
            Wait
            Print a message
            Signal
    This lets the driving process coordinate with this one better than the simple Wait
    loop does.
*/
#include <stdio.h>
#include <events.h>
#include <ctype.h>
#include <errno.h>
#include <const.h>

#define TRUE            1
#define FALSE           0
#define FOREVER         TRUE
```

Figure 11.1: Counting Semaphore Rules

Wait increment	-1
Signal increment	1
Initial value	The same as the initial number of resources, *n*.
Values	The value of the semaphore should range from 0, indicating that there are no free resources, to *r*, the maximum number of free resources. The initial number of resources is not necessarily the maximum number. In fact, it is common to start with a semaphore value of zero, signifying that there are no free resources until a process creates them and signals the semaphore to that effect.
Wait range	1 to *r* is enough, but if there is a chance that Ev$Signal may over-increment the event, use 1 to maxint (1 to 2147483647).
Activate-all	Use FALSE.
SemWait or P	Use `Ev$Wait`.
SemSignal or V	Use `Ev$Signal`.

Examples

Initial Value	Wait Increment	Signal Increment	Comment
4	-1	1	A buffer pool that initially contains four free buffers.
0	-1	1	An empty buffer pool.
256	-1	1	A stack-protocol resource. The value returned by `Ev$Wait` is the index of the entry allocated by that `Ev$Wait`. This only works if resources are returned FIFO.

```
char *Wait_EName=NULL,
*Signal_EName=NULL;

event_id Wait_Event, Signal_Event;
int32 Wait_Min, Wait_Max;

/*
    Prototypes
*/
void Process_Parms(int argc, char **argv);
void Link_To_Events(void);
void EvUnlink(void);
static process_id getpid(void);

main(int argc, char **argv)
{
    int32 Old_Value;

    Process_Parms(argc, argv);
    Link_To_Events( );

    while(FOREVER){
        if(_os9_ev_wait(Wait_Event, &Old_Value,
                Wait_Min, Wait_Max) != SUCCESS){
            fprintf(stderr, "Failure in ev_wait.  Errno %d\n",
                    errno);
            exit(errno);
        }
        printf("%d:%d\n", getpid( ), Old_Value);
        if(Signal_EName == NULL)
        continue;
        if((errno = _os_ev_signal(Signal_Event, &Old_Value, FALSE)) != SUCCESS){
            fprintf(stderr, "Failure in ev_signal.  Errno %d\n",
                    errno);
            EvUnlink( );
            exit(errno);
        }
    }
    EvUnlink( );
    exit(0);
}


void Process_Parms(int argc, char **argv)
{
    register int ptr;

    if(argc <3){
        printf("%s needs at least three parameters. Usage:\n%s %s\n",
                *argv, *argv,
                "Wait_Event [Signal_Event] Activation_Max Activation_Min");
        exit(1);
    }
    Wait_EName = argv[1];
    if((!isdigit(*argv[2])) && (*argv[2] != '-')){/*Signal_EName */
        Signal_EName = argv[2];
        ptr = 3;
    }else
        ptr = 2;
    Wait_Min = atoi(argv[ptr]);
    if(argc <= ptr+1)
        Wait_Max = Wait_Min;
    else
        Wait_Max = atoi(argv[ptr+1]);
    return;
}


void Link_To_Events()
{
    if((errno = _os_ev_link(Wait_EName, &Wait_Event)) != SUCCESS){
        fprintf(stderr, "Failure in ev_link to %s. Error %d\n",
                Wait_EName, errno);
        exit(errno);
    }
    if(Signal_EName)
        if((errno= _os_ev_link(Signal_EName, &Signal_Event)) != SUCCESS){
            fprintf(stderr, "Failure in ev_link to %s. Error %d\n",
                    Signal_EName, errno);
            exit(errno);
        }
}


void EvUnlink()
{
    _os_ev_unlink(Wait_Event);
    if(Signal_EName)
        _os_ev_unlink(Signal_Event);
}
```

```
static process_id getpid()
{
    process_id id;
    u_int16 dummy;
    _os9_id(&id, &dummy, &dummy, &dummy);
    return id;
}
```

The next program is the driver for the semaphore experiments. It can be used for both the simple (Wait), and the synchronized (Signal/Wait), protocols.

```
/*
    Semaphore
    This is the driver for the semaphore experiments. It is used:
            Semaphore Event1 [Event2]
    Event1 is the event which this process will signal and SyncWait will wait for. If
    Event2 is given, this process will wait for that event after it signals Event1.
*/
#include <stdio.h>
#include <events.h>
#include <errno.h>
#include <const.h>

#define TRUE   1
#define FALSE  0
#define LOOPS 100

main(int argc, char **argv)
{
    char *WaitEvent=NULL;
    char *SignalEvent=NULL;
    event_id WEvent, SEvent;
    int i;
    int32 Old_Value;

    if(argc <2){
        printf("%s Usage:\n %s SignalEvent WaitEvent\n", *argv, *argv);
        exit(1);
    }
    SignalEvent = argv[1];
    if((errno = _os_ev_link(SignalEvent, &SEvent)) != SUCCESS){
        fprintf(stderr, "Error %d in ev_link for %s\n",
                errno, SignalEvent);
        exit(errno);
    }
```

```
if(argc >2){
    WaitEvent = argv[2];
    if((errno = _os_ev_link(WaitEvent, &WEvent)) != SUCCESS){
        fprintf(stderr, "Error %d in ev_link for %s/n",
                errno, WaitEvent);
        exit(errno);
    }
    for(i=0;i<LOOPS;++i){
        (void)_os_ev_signal(SEvent, &Old_Value, FALSE);
        if(WaitEvent)
            _os9_ev_wait(WEvent, &Old_Value, 1, 2147483647);
        else{
            u_int32 Sleep_Time = 20;          /*ticks */
            _os9_sleep(&Sleep_Time);
        }
    }
    exit(0);
}
```

The following steps should make two different number pairs alternate on the screen, but before the semaphore's value drops to zero, there'll be a rush of numbers. Right after you start the first ***syncwait*** process, you'll see its process number and the event values 4, 3, 2, and 1 appear:

```
+7
7:4
7:3
7:2
7:1
```

Now the semaphore has been reduced to a value of zero, and the experiment will not increase it above one unless something prevents the ***syncwait*** programs from executing as fast as ***semaphore.***

Stop the display for a while (causing the ***semaphore*** to get ahead of the ***syncwait*** s), and note what happens when you let it go.

Stop the experiment with a control-C, or by waiting for it to end. Then kill the remaining ***syncwait*** and ***semaphore*** processes. Deleting the event with ***EvDel*** will remove the event and kill all the processes waiting on the event.

The experiment in figure 11.3 uses a hand-shaking protocol. You will find that the numbers fly by much faster. If you stop the display, ***semaphore*** waits, so stopping the display only has the obvious effect (the display pauses).
Stop the experiment and clean up as before.

Figure 11.2: **Sample Semaphore Experiment**

```
$ evcreate Wait −1 1 4
$ syncwait Wait 1 100&
$ syncwait Wait 1 100&
$ semaphore Wait&
$ w
```

Figure 11.3: **Another Experiment with Semaphores**

```
$ evcreate Wait −1 1 4
$ evcreate Sig −1 1 0
$ syncwait Wait Sig 1 4
$ syncwait Wait Sig 1 4
$ semaphore Wait Sig
```

11.4 Events as Selectors

OS-9 events can do much more than semaphores. Instead of behaving like on/off switches, they can act like elaborate selector switches. First let's build a selector that just turns clockwise through ten selections. It turns on 1, then 2, then 3, …, then 10, then 1 and around again. This is done by setting the Ev$Wait increment to zero. Making Ev$Signl or Ev$Pulse increment the variable is easy. Finding a way to set it from 10 back down to 1 is trickier.

If the selector corresponds to some physical mechanism like the sectors on a disk track or the scan lines on a CRT display, an arrangement for events is:

Ev$Creat
  initial value 0 (initially off-scale)
  auto-increment for Ev$Wait: 0
  auto-increment for Ev$Signl: 0
Ev$Wait
  min = max = trigger selection for this process (1..10)
Ev$Signl
  not used
Ev$Set
  event value from the hardware (scan line or whatever)

If the event it driven with Ev$Signl, the auto-increments must be large enough that each Ev$Wait throws the event's value entirely out of the range of selections. If it doesn't do that, it can cause another Ev$Wait to unblock. If the Ev$Wait increment is 0, a process stays unblocked until the event is set or signaled. You can try it with the next example program. Set the auto-increment for Ev$Wait to 0 and the auto-increment for Ev$Signl to 1, then convert code around the _os_ev_pulse() function call to the following

```
        _os_ev_signal(SEvent, &Event_Value, FALSE);
    }
    Event_Value = 0;
    _os_ev_set(SEvent, &Event_Value, FALSE);
}
```

Everything works fine except that each time a process is selected, it executes at least a dozen times.

If the selector is not controlled by hardware and there is more than one process setting the event, we need a subsidiary semaphore to protect a Ev$Read/Ev$Set pair. If there is only one process setting the event, the following arrangement will work:

Ev$Creat
  initial value −10 (initially off scale)
  auto-increment for Ev$Wait: −10
  auto-increment for Ev$Signl: 11
Ev$Wait
  min = max = trigger selection for this process
Ev$Signl
  start only one process
Ev$Set
  used every tenth time to set the event variable to 1

The following example implements a ten-position selector-event to drive tasks that wait on the values 1 through 10. For this kind of event, we don't usually worry about synchronization. The processes waiting for the event are supposed to complete before the event comes around to them again, or at least not fail if they miss a turn. An _os9_sleep() in the driver makes the demonstration easier to watch. It slows down the rotation of the selector until the numbers can easily be displayed in the time between Ev$Pulses.

```
/*
    Selector:
    This program is used to experiment with events as selectors.
    Usage:
            Selector Event_Name
    The event name should be the same name that a bunch (10) of syncwaits are
    waiting for.
```

```
*/
#include <stdio.h>
#include <events.h>
#include <errno.h>
#include <const.h>

#define LOOPS 100
#define FALSE  0

main(int argc, char **argv)
{
    char *SignalEvent=NULL;
    event_id SEvent;
    int32 Event_Value;
    int i, j;
    u_int32 Sleep_Time;

    if(argc <2){
        printf("%s Usage:\n %s SignalEvent\n", *argv, *argv);
        exit(1);
    }
    SignalEvent = argv[1];
    if((errno = _os_ev_link(SignalEvent, &SEvent)) != SUCCESS){
        fprintf(stderr, "Error %d in ev_link for %s\n",
                errno, SignalEvent);
        exit(errno);
    }
    for(i=0; i<LOOPS; i++){
        for(j=1; j<10; j++){
            Sleep_Time = (0x80000000 |20);
            _os9_sleep(&Sleep_Time);
            Event_Value = j;
            (void)_os_ev_pulse(SEvent, &Event_Value, FALSE);
        }
    }
    (void)_os_ev_unlink(SEvent);
    exit(0);
}
```

The example in figure 11.4 repeatedly produces pairs of numbers containing 1–10. You may need ten control-C's to stop it, or you may be able to kill ***selector*** and the ***syncwait*** s with a ***kill*** command.

It's interesting to watch what happens if you kill a few ***syncwait***'s and leave ***selector*** running.

Figure 11.4: **Sample Event Selector Experiment**

```
$ evcreate Wait 0 0 0
$ syncwait Wait 1&
$ syncwait Wait 2&
$ syncwait Wait 3&
$ syncwait Wait 4&
$ syncwait Wait 5&
$ syncwait Wait 6&
$ syncwait Wait 7&
$ syncwait Wait 8&
$ syncwait Wait 9&
$ syncwait Wait 10&
$ selector Wait&
$ w
```

Probably the simplest application of events is selecting numbers on demand. The `Ev$Pulse` call jumps to a value out of sequence and back. The `Ev$Set` call sets the variable to a particular value, and `Ev$SetR` sets the variable up or down by the specified amount. These three operations allow the programmer plenty of flexibility in twisting the selector knob.

Processes doing `Ev$Wait`s can be more flexible than those in the above examples. They don't need to wait on one value. They can wait for any value in a range. You can set an `Ev$Wait` to unblock for any of a number of consecutive values.

A computer monitoring a house's security system can have many processes in `Ev$Wait`s blocked for each event. When a door opens, it could unblock a process for that particular door, and another process that was waiting for any door on the ground floor, and two other processes that reassure the motion detectors on either side of the door.

Chapter 12

Binary Semaphores

Binary semaphores are a strictly limited but very fast mechanism for process synchronization.
A semaphore can be implemented with no kernel support, but is more efficient if it is backed with some blocking service. For OS-9 the obvious possibilities are a wait loop, `F$Sleep`*,* `F$Event`*, and now* `F$Sema`*. This chapter includes examples of all four types.*

12.1 Principles of Operation

A semaphore is a simple device that acts as a valve in a system. Related semaphores can appear in many processes. When any process passes one of the semaphores, it makes all the other semaphores block. Any other process that reaches a semaphore will queue up and pass the semaphore one at a time. The blocking component of a semaphore is usually called *wait* or *P.* Another part, usually called *signal* or *V,* unblocks the semaphore long enough to let one process through.

The P operation is a gate that lets only one process at a time through. The V operation is the trigger that lets a process through the gate. A semaphore can be either initially open or initially closed.

The most common classes of semaphore use are resource locking (door) and producer/consumer (barrier). If a semaphore is initially open it works like the door on a private room…say a telephone booth. When you want to use the booth you say *P.* If the booth is empty the door opens and you go in. If the booth is full the door stays closed and you must wait. When you leave the booth you say *V.* If people are waiting that lets one person in. If no one is waiting the *V* just leaves the door ajar.

If a semaphore is initially closed it works like a gatekeeper's barrier. As people arrive at the barrier they say *P,* but nobody will pass until the gatekeeper lifts the barrier by saying *V.* Lifting the barrier lets one person through.

12.1.1 Busy Waiting Semaphores

The simplest possible semaphore is only three instructions long:

```
waitloop    tas       flag(a0)
            bne.b     waitloop

signal      clr.b     flag(a0)
```

The wait code loops until flag becomes zero, then it sets a bit in the flag byte to claim the semaphore. To release the semaphore the signal code clears the flag byte. This technique is called busy waiting. This is the fastest way to claim a free lock, but it wastes CPU time looping if it has to wait. Busy waiting sometimes makes sense as a locking mechanism in a multiprocessor system, but busy waiting works better if the main wait loop doesn't include the complex `tas` instruction:

```
waitloop    tst.b     flag(a0)
            bne.b     waitloop
            tas       flag(a0)
            bne.b     waitloop

signal      clr.b     flag(a0)
```

This technique is called test-and-test-and-set. It doesn't use a `tas` until it has good reason to believe the flag will be zero.

12.1.2 Sleeping Semaphores

The processor load imposed by the busy wait loop can be reduced by inserting a `F$Sleep`:

```
waitloop    tas       flag(a0)
            beq.b     Gotit
            move.w    #1,d0
            os9       F$Sleep
            bra.b     waitloop
Gotit

signal      clr.b     flag(a0)
```

The sleep may introduce at least a one-tick delay between the time the semaphore is released and the time a waiting process claims it, but the technique is simple. When contention[1] for a semaphore is rare, busy waiting with a sleep in the loop is often adequate.

12.1.3 Semaphores Built on Events

It is easy to use events to implement semaphores. Chapter 11 shows how to build counting semaphores from events. Events are a satisfactory solution when the semaphore is heavily used, but often a semaphore is used to protect a resource that will almost never experience contention. If the protection of a semaphore is not used the application will crash every few hours, but it seems foolish to call for the full power of events and almost never use it. A `tas` is about 100 times faster than an `Ev$Wait` and it is enough to lock a resource.

Events can be combined with a `tas` to give an improved solution. The code is a little more complicated than busy waiting, but the result uses the scheduling power of events when it is required, and has the speed of `tas` when the semaphore need not wait.

```
                  nam     Semaphore
                  ttl     Event Semaphore
                  use     <oskdefs.d>
                  opt     -l
                  psect   FSem,0,0,0,200,0
           *
           * EWait
           *
           * d0 Is the event ID number for the semaphore's event
           *      The event must have
           *              an initial value of 0,
           *              a wait increment of -1,
           *              a signal increment of 0.
           *      d1 Is a pointer to the event byte.
           *              The high order bit of the byte is controlled by a tas.
           *              The other bits are a count of waiting processes (in the range 0 to 127)
           *      returns 0 for success or -1 for an error (and stores the error code in errno)
           *
0000 2f08  EWait: move.l  a0,-(sp)
0002 2041         move.l  d1,a0
0004 5210         addq.b  #1,(a0)          Request a signal
0006 4ad0  loop   tas     (a0)
0008 6a24         bpl.b   GotIt
000a 48e7         movem.l d2-d3,-(sp)
           * d0 is already the event ID number
000e=7200         moveq   #Ev$Wait,d1
```

[1] Contention is competition. When processes almost never have to wait for a semaphore, contention is light.

```
0010 7401            moveq   #1,d2            Minimum activation value
0012 2602            move.l  d2,d3            Maximum activation value
0014=4e40            os9     F$Event
0018 6506            bcs.b   WError
001a 4cdf            movem.l (sp)+,d2–d3
001e 60e6            bra.b   loop
0020 48c1  WError    ext.l   d1
0022=2d41            move.l  d1,errno(a6)
0026 70ff            moveq   #–1,d0
0028 4cdf            movem.l (sp)+,d2–d3/a0
002c 4e75            rts
002e 7000  GotIt     moveq   #0,d0
0030 205f            move.l  (sp)+,a0
0032 4e75            rts

           *
           * ESignal
           *         d0 is the event ID number for the semaphore event
           *         d1 is a pointer to the event byte
           *
0034 2f08  ESignal:  move.l  a0,–(sp)
0036 2041            move.l  d1,a0            Make byte pointer useful
0038 0890            bclr    #7,(a0)          Clear the flag bit
003c 5310            subq.b  #1,(a0)          Uncount this process
003e 6712            beq.b   SigDone
0040 2f02            move.l  d2,–(sp)
0042 243c            move.l  #1,d2            Signal waiter
0048=7200            moveq   #Ev$Set,d1
004a=4e40            os9     F$Event          Signal a process
 004e 6508           bcs.b   SError
0050 241f            move.l  (sp)+,d2
0052 205f  SigDone   move.l  (sp)+,a0
0054 7000            moveq   #0,d0            Good return
0056 4e75            rts
0058 48c1  SError    ext.l   d1
005a=2d41            move.l  d1,errno(a6)
005e 70ff            moveq   #–1,d0           Error return
0060 4cdf            movem.l (sp)+,d2/a0
0064 4e75            rts
00000066             ends
```

The counter for waiting processes is only 7 bits long. It could easily be expanded to 15 or 31 bits by changing the size of the `addq` and `subq` instructions, but 127 is a large number of waiting processes, especially for a semaphore with light contention.

Although `tas` is a multi-processor instruction, `addq` and `subq` are not. Multi-processor event-semaphores use more complicated strategies to count waiting processes.

This implementation of a binary semaphore is not *fair*. A process waiting in the event is not guaranteed to get out of EWait( ) before a process that arrives later. This is not a problem if event-semaphores are used when contention for the semaphore is light. When contention is heavy, a more elaborate version of ESignal( ) could solve the problem, but this implementation of semaphores is aimed at situations where contention is light, so a *fair* ESignal( ) is difficult to justify.

The code to call ESignal( ) and EWait( ) looks like:

```
#include <stdio.h>
#include <module.h>
#include <events.h>
#include <errno.h>
#include <const.h>

#define TRUE   1
#define FALSE  0
/*
   ESemTst EventName
   The event must already be created with an initial value of 0, a signal
   increment of 0, and a wait increment of −1.
*/

void *ModPtr;

/*
   Prototypes
*/
void *GetDMPtr(char *);
void ReleaseDM(void);
static process_id getpid(void);

main(int argc, char **argv)
{
   event_id SemID;
   void *SemPtr;
   /*
      Find or create a data module for the event. The data module has the
      same name as the event.
   */
   (void)_os_ev_link(argv[1], &SemID);
   SemPtr = GetDMPtr(argv[1]);
   while(TRUE){
      EWait(SemID, SemPtr);
      printf("%d ", getpid());
      fflush(stdout);
      ESignal(SemID, SemPtr);
```

```
    }
    (void)_os_ev_unlink(SemID);
    ReleaseDM( );
}


void *GetDMPtr(char *name)
{
    Mh_com ptr;
    Mh_exec DPtr;
    u_int16 TypeLang=0, AttrRev = (MA_REENT*256)+1;

    if((errno = _os_link(&name, &ptr, (void **)&DPtr,
            &TypeLang, &AttrRev)) != SUCCESS)
        if((errno = _os_mkmodule(name, 1, &AttrRev,
                &TypeLang, (u_int32)0x07777,
                (void **)&DPtr, &ptr, 0)) != SUCCESS){
            perror("mkdata module failed");
            exit(errno);
        }
    ModPtr = ptr;                   /*save pointer value  */
    return (DPtr);
}


void ReleaseDM( )
{
    _os_unlink(ModPtr);
}


static process_id getpid( )
{
    process_id id;
    u_int16 dummy;
    _os9_id(&id, &dummy, &dummy, &dummy);
    return id;
}
```

The following script demonstrates the event-semaphore test program:

```
$ evcreate esem –1 0 0
$ esemtst esem &
$ esemtst esem &
$ esemtst esem &
```

Since there is no handshake protocol in ***esemtst***, each process prints its process ID several times, then the next process gets control of the semaphore.

The ***esemtst*** processes can be killed with control-C's or the kill command, and the esem event can be deleted with ***evdel***.

12.1.4 Semaphores Built on `F$Sema`

In version 3.0 Microware added kernel support for binary semaphores to OS-9. Like the implementation in the previous section, binary semaphores consist of library code and a system call. The library code evolved from the code in the previous section. The system call is an entirely new SVC optimized for speed when it works in conjunction with the library code.

The library code maintains a 48-byte semaphore data structure that is provided by the caller. This structure is used by the library code and kernel to store semaphore-related data.

Everything except blocking and unblocking is done in library code. When the library code finds that a caller must block or release a blocked process, it uses the `F$Sema` SVC. Semaphores are particularly aimed at the type of lock that is usually contention-free: locks that almost never have a queue of processes eager for access. Semaphore operations with no contention are handled entirely in the library. Since they have no system call overhead, semaphore operations that complete in the library code are about ten times as fast as semaphore calls that use `F$Sema`. This is not to say the the kernel implementation of semaphores is slow. Under the atomic kernel `F$Sema` is about 10% faster than `F$Event`, and with the full kernel and SSM protection `F$Sema` is about 15% slower than `F$Event`.[2]

The most common locations for semaphores are:

- One or more semaphores are included in a data module. The semaphores are used to lock other data structures located in the same data module.

- One or more semaphores are included in a process' static or dynamic storage. These semaphores are used for communication with system state code: drivers, system calls, or system state processes.

  Memory owned by a process should only be used for a semaphore with extreme care. If the process dies, the memory may be allocated for another use without any notification to the system code that is also using the semaphore.

  `F$Sema` uses SSM to check the caller's access to the semaphore control block if the caller is in user-state, but system state calls are unprotected.

[2] SSM slows `F$Sema` because the kernel must ensure that a process has write access to the semaphore data structure before it permits the process to use the semaphore.

- Semaphores are embedded in system data structures to allow system state code to implement mutual exclusion without disabling preemption or masking interrupts.

Process Termination

The kernel's process termination code does nothing about semaphores. Most important, if a process is terminated unexpectedly while it is holding a semaphore, that semaphore remains locked. Any application that intends to survive that class of failure needs to include some type of watch-dog code to notice the failure, check and repair the affected data structures, and release the semaphore.

The kernel cannot simply release semaphores when the processes holding them terminate. If a process holds a semaphore, the kernel must assume that the semaphore protects a data structure that may be inconsistent.

Binary semaphores are less forgiving than most OS-9 constructs. They depend on careful preparation before each system call. Even minor failures to follow the protocol cause trouble. Sometimes a bug manifests as an error returned from the system, but the bugs I've experienced in programs that use semaphores usually appear as processes that don't wake up or won't wait.

12.1.5 The Semaphore Library Code

The semaphore library includes four functions: _os_sema_init(), _os_sema_term(), _os_sema_p(), and _os_sema_v(). The 3.0 release of the semaphore library implements _os_sema_init() and _os_sema_term() without kernel support, but it seems very likely that a future release will add enhanced kernel support that will only work with updated libraries that call the kernel for initialization and termination.

_os_sema_init()

Initialize the semaphore data structure before using it for synchronization. `F$Sema` makes an effort to detect and correct uninitialized semaphores, but it costs time and is not fool-proof.

The following code is contained in the _os_sema_init() library function. It initializes a semaphore data structure.

```
#include <semaphore.h>
#include <const.h>
#include <stddef.h>
#include <sysglob.h>

#define SEMA_SYNC 0x204A6F6E
```

```
/*_os_sema_init – initialize the use of a semaphore.   */
_os_sema_init(sema)
 semaphore *sema;
{
    unsigned x;
    unsigned mpu;
    char buff[80];

    if (sema→s_sync != SEMA_SYNC) {
        sema→s_value = 0;
        sema→s_lock = 0;
        sema→s_length = 0;
        sema→s_qnext = sema→s_qprev = NULL;
        sema→s_owner = 0;
        sema→s_sync = SEMA_SYNC;
        sema→s_flags &= ( S_CASFLAG);
        if (_os_getsys(offsetof(sysglobs,d_mputyp),4,(glob_buff*)&mpu) == SUCCESS)
            if ((mpu >= 68000) && (mpu <= 69000))
                if (mpu >= 68020)
                    sema→s_flags |= S_CASFLAG;
    }
    return SUCCESS;
}
```

_os_sema_p()

The P() library code is similar to the event-based semaphore-wait function in the previous section. The primary improvement is that _os_sema_p() uses the F$Sema SVC instead of F$Event. Note that F$Sema expects a pointer to the semaphore data structure in D0 and a function code of 1 in D1.

```
                    psect   os_sema_p_a,0,0,0,0,0
00000000            org     0
00000000  s_value   do.l    1
00000004  s_lock    do.l    1
00000008  s_qnext   do.l    1
0000000c  s_qprev   do.l    1
00000010  s_length  do.l    1
00000014  s_owner   do.l    1
00000018  s_user    do.l    1
0000001c  s_flags   do.l    1
00000020  s_sync    do.l    1

00000001  P_OP      set     1
```

```
00000002  V_OP        set      2

               * _os_sema_p - reserve semaphore (acquire exclusive access).
               * _os_sema_p(sema)
               * semaphore *sema;
0000 c188  _os_sema_p: exg.l   d0,a0              save register
 0002 52a8              addq.l  #1,s_lock(a0)      increment lock count (user count)
0006 4ae8  _os_sema_ptas tas   s_value(a0)        test and set semaphore
000a c188              exg.l   d0,a0              restore register
000c 6604              bne.s   _os_sema_poptn     bra if in use
000e 7000              moveq.l #0,d0              return SUCCESS (semaphore reserved)
0010 4e75              rts

0012 48e7  _os_sema_poptn movem.l d1/a0,–(a7)save registers
0016 2040              movea.l d0,a0              get pointer to semaphore structure
0018 7201  _os_sema_poptn05 moveq.l #P_OP,d1flag P operation
001a=4e40              os9     F$Sema             wait for the V operation
 001e 650e             bcs.s   _os_sema_perr      abort on error
0020 4ae8              tas     s_value(a0)        test and set semaphore
0024 66f2              bne.s   _os_sema_poptn05 bra if semaphore busy
0026 7000              moveq.l #0,d0              return SUCCESS (semaphore reserved)
0028 4cdf  _os_sema_rts movem.l (a7)+,d1/a0       restore registers
002c 4e75              rts
002e 2001  _os_sema_perr move.l d1,d0             copy error
0030 60f6              bra.s   _os_sema_rts       return error
00000032               ends
```

_os_sema_v( )

The _os_sema_v( ) library function is similar to the event-based semaphore-signal( ) function. It has two major enhancements:

1. _os_sema_v( ) checks the processor type stored in the semaphore structure by _os_sema_init( ). If the processor supports the `cas` instruction, the p( ) code uses `cas` to clear the semaphore lock. This is slower than a `moveq`, but `cas` writes through the data cache.

2. _os_sema_v( ) uses the `F$Sema` SVC instead of `F$Event`. Note that `F$Sema` expects a pointer to the semaphore data structure in D0 and a function code of 1 in D1.

```
                       psect   os_sema_v_a,0,0,0,0,0
00000000               org     0
00000000  s_value      do.l    1
00000004  s_lock       do.l    1
00000008  s_qnext      do.l    1
```

```
0000000c  s_qprev   do.l    1
00000010  s_length  do.l    1
00000014  s_owner   do.l    1
00000018  s_user    do.l    1
0000001c  s_flags   do.l    1
00000020  s_sync    do.l    1

00000001  P_OP      set     1
00000002  V_OP      set     2
00000000  CAS_OK    set     0

          * _os_sema_v - release semaphore (release exclusive access).
          * _os_sema_v(semaphore *sema)

0000 48e7 _os_sema_v: movem.l d1/a0,–(a7)   save registers
 0004 2040          movea.l d0,a0           get pointer to semaphore
0006 0828           btst.b  #CAS_OK,s_flags+3(a0) check for availability of CAS instruction
000c 6730           beq.b   _os_sema_clr    bra if not available
000e 7200           moveq.l #0,d1           clear register
0010 103c           move.b  #$80,d0         get reserve value
0014 0ae8           cas.b   d0,d1,s_value(a0) release semaphore (non-cached instruction)
001a 53a8 _os_sema_v05 subq.l #1,s_lock(a0) decrement lock count (use count)
001e 6608           bne.b   _os_sema_busy   bra if other processes waiting
0020 7000 _os_sema_vok moveq.l #0,d0        return SUCCESS
0022 4cdf _os_sema_exit movem.l (a7)+,d1/a0 restore registers
0026 4e75           rts
0028 6b0e _os_sema_busy bmi.b _os_sema_vadd1
002a 2008           move.l  a0,d0           get pointer to semaphore
002c 7202           moveq.l #V_OP,d1        flag V operation
002e=4e40           os9     F$Sema
0032 64ec           bcc.b   _os_sema_vok    bra if no error
0034 2001           move.l  d1,d0           copy error
0036 60ea           bra.b   _os_sema_exit

          * Restore the lock count to zero
0038 52a8 _os_sema_vadd1 addq.l #1,s_lock(a0) restore lock count
003c 60e2           bra.b   _os_sema_vok

          * Release the semaphore for MPU's < 68020
003e 42a8 _os_sema_clr clr.l s_value(a0)    release semaphore
0042 60d6           bra.b   _os_sema_v05
00000044            ends
```

_os_sema_term( )

The _os_sema_term( ) function is mainly a place-holder in case an improved version of semaphores needs serious termination.

```
#include <semaphore.h>
#include <const.h>

/*_os_sema_term – terminate useage of a semaphore.   */
_os_sema_term(sema)
 register semaphore *sema;
{
    sema→s_sync = 0;                              /*invalidate the semaphore */
    return SUCCESS;
}
```

12.1.6 Caching and MP Concerns

The cas instruction is slower than move, but the library code uses cas to zero the lock byte for partial compatibility with any future shared-memory multiprocessor implementations and to avoid any possible difficulties with the cache. Tas and cas are designed for shared-memory multiprocessor systems. Both instructions access memory without relying on the cache. Caches associated with processors are required to make a shared-memory multiprocessor perform well, but private caches also cause mysterious problems. If the value in the cache is overlooked in favor of the one in memory, the following sequence will fail:

```
(semlock is $80)
        move.b #0,semlock(a0)
(time passes,
    but not enough to cause the new value for semlock to be flushed from the cache).
    Another processor executes the following statement:
        tas semlock(a0)
(memory is still $80,
    so tas will think the semaphore is still reserved)
```

This problem can only happen on systems with copy-back caching enabled. Write-through caches always leave the cache consistent with memory except, possibly, in the middle of instructions.

The library code uses addq and subq instructions to manipulate the count of processes that are waiting for the semaphore. These instructions are indivisible on a uni-processor but in a shared-memory multiprocessor they are not atomic. Two processors could interleave their memory accesses like this:

processor 1	**processor 2**
reads the counter == 1	
calculates 1+1	reads the counter == 1
writes 2	calculates 1+1
	writes 2

If the two `addq` instructions had not interleaved the result would have been three. An operation sequence that results in two will cause one of the process to be stuck waiting for the semaphore.

Almost any operation can be implemented atomically with `cas` or `cas2`. Here's the implementation of `add`:

```
* implements (a0) += d0
* leaves the old value of (a0) in d1
* leaves the result in (a0) and d0
        move.l  d0,-(sp)        save d0
loop    move.l  (a0),d1         get (a0)
        add.l   d1,d0
        cas.l   d1,d0,(a0)      save d0 if (a0) has not changed
        beq.b   done
        move.l  (sp),d0
        bra.b   loop
done    addq.l  #4,sp           clear stack
        rts
```

12.1.7 Index Card Module

This program demonstrates a shared data structure with many locks. A single semaphore locking the entire card file would have been easier to program, but fine-grained locking lets more processes access the structure concurrently.

The best grain for locking depends on the memory and performance cost of the locks compared with the advantage of concurrency. For a computer with one processor, concurrency isn't a significant advantage unless the locks cover a lot of data. A prime example would be a program that must acquire a lock then wait for input. If somebody locks a block of data then goes out to lunch, we'd better hope that the lock covers very little data or that everybody else goes out to lunch too.[3] That class of work justifies serious effort to reduce the scope of locks.

```
#include <stdio.h>
#include <module.h>
#include <errno.h>
#include <semaphore.h>
```

[3] If all else fails hope that it is a short lunch.

```
#include <const.h>

/*
    This process maintains a linked list in a public data module named
    cardfile.module. It has three operations:
            add
            del
            list
    Any number of processes can operate on the module concurrently pro-
    vided that they all use semaphore locking protocols.
*/
#define MODULE_NAME          "cardfile.module"
#define KEYLEN               8
#define DATALEN              100
#define ENTRIES              100
#define FLAG                 0xffff

typedef enum {FALSE, TRUE}boolean;
typedef enum {none, list, add, delete}operations;
typedef u_int16 NodeIndex;

typedef struct {
    NodeIndex Next;
    char Key[KEYLEN];
    char Data[DATALEN];
    semaphore Lock;
}cfnode;


typedef struct {
    NodeIndex Freelist;
    NodeIndex First;
    semaphore Lock;
}cfhead;


typedef struct {
    cfhead Header;
    cfnode Node[ENTRIES];
}cf, *CF;


/*Prototypes */
static operations Process_Args(int, char **);
static error_code Findcardfile(char *);
static void Cleanup( );
static void Listcardfile(void);
static boolean FindFreeNode(void);
static char *GetEntryData(void);
static char *GetEntryKey(void);
static void InitCF(CF);
static void Insert(char *, char *);
static boolean FindEntry(char *);
static void Delete(void);
static void PrintNode(cfnode *);
static void Usage(void);

main(int argc, char **argv)
{
    char *Data, *Key;
    operations op;

    if((op = Process_Args(argc, argv)) == none)
        exit(0);

    if(Findcardfile(MODULE_NAME) != SUCCESS){
        perror("find cardmodule");
        exit(errno);
    }
    switch(op){
        case list:
                Listcardfile( );
                break;
        case add:
            if(! FindFreeNode( ))
                fprintf(stderr, "The cardfile is full\n");
            else {
                Data = GetEntryData( );
                Key = GetEntryKey( );
                Insert(Key, Data);
            }
            break;
        case delete:
            Key = GetEntryKey( );
            if(FindEntry(Key))
                Delete( );
            else
                fprintf(stderr, "Key %s not found in cardfile\n",
                        Key);
            break;
        default:
            exit(1);
    }
    Cleanup( );
    exit(0);
}


static operations Process_Args(int argc, char **argv)
{
    char *ptr;
    for(argc––, argv++; argc != 0; argc––, ++argv)
        if(**argv == ’–’)
            for(ptr = *argv+1; *ptr != ’\0’ ; ++ptr)
                switch(*ptr){
                    case ’l’:
                    case ’L’:
                        return list;
                    case ’a’:
                    case ’A’:
                        return add;
                    case ’d’:
                    case ’D’:
                        return delete;
                    case ’?’:
                    default:
                        Usage( );
                        return none;
                }
    Usage( );
    return none;
}


/*
    Data input functions
*/
static char *GetEntryData(void)
{
    static char Data[DATALEN+1];

    printf("Data:"); fflush(stdout);
    fgets(Data, DATALEN, stdin);
    if(strlen(Data) != DATALEN)
        Data[strlen(Data)–1] = ’\0’;            /*zap \n */
    return Data;
}


static char *GetEntryKey(void)
{
    static char Key[KEYLEN+1];

    printf("Key:"); fflush(stdout);
    fgets(Key, KEYLEN, stdin);
    if(strlen(Key) != KEYLEN)
        Key[strlen(Key)−1] = '\0';          /*zap \n */
    return Key;
}


/*
    Locate or create the cardfile module. Initialize local variables that
    refer to the cardfile.
*/
static void *cardfile_Head;
static cfhead *Header;
static cfnode *Nodes;

static error_code Findcardfile(char *name)
{
    mh_com *head;
    CF data;
    const u_int16 datasize = sizeof(cf);
    u_int16 TypeLang=mktypelang(MT_DATA,ML_ANY);
    u_int16 AttrRev=0;

    if((errno = _os_link(&name, &head, (void **)&data, &TypeLang, &AttrRev)) != SUCCESS){
         AttrRev = mkattrevs(MA_REENT, 1);
        if((errno = _os_mkmodule(name, datasize, &AttrRev, &TypeLang,
                MP_OWNER_READ | MP_OWNER_WRITE |
                MP_GROUP_READ | MP_GROUP_WRITE |
                MP_WORLD_READ | MP_WORLD_WRITE,
                (void **)&data, &head, 0)) == SUCCESS){
            /*Extra link to hold the module in memory */
            (void)_os_link(&name, &head, (void **)&data, &TypeLang, &AttrRev);
            InitCF(data);
        }else
            return errno;
    }
    cardfile_Head = head;
    Header = &data→Header;
    Nodes = data→Node;
    return SUCCESS;
}


static void InitCF(CF cf)
{
    NodeIndex i;

    /*Initialize header lock */
    _os_sema_init(&(cf→Header.Lock));
     /*and lock it */
    _os_sema_p(&(cf→Header.Lock));

    /*Initialize cardfile list */
    cf→Header.First = FLAG;

    /*Initialize free list */
    cf→Header.Freelist = 0;
    for(i = 0; i < ENTRIES−1; ++i)
        cf→Node[i].Next = i+1;
    cf→Node[i].Next = FLAG;
    _os_sema_v(&(cf→Header.Lock));
}


/*Unlink the cardfile module and do any other cleanup. */
static void Cleanup( )
{
    (void)_os_unlink((mh_com *)cardfile_Head);
 }


/*
    cardfile maintenance functions
*/
static void Listcardfile(void)
{
    NodeIndex i, tmp;

    i=Header→First;
    while(i != FLAG){
        _os_sema_p(&Nodes[i].Lock);
```

```
            PrintNode(&(Nodes[i]));
            tmp = i;
            i = Nodes[i].Next;
            _os_sema_v(&Nodes[tmp].Lock);
        }
}


static void PrintNode(cfnode *Node)
{
    printf("Key: %s\nData: %s\n", Node→Key, Node→Data);
}


static NodeIndex ReservedNode=FLAG;

static void Insert(char *Key, char *Data)
{
    if(ReservedNode == FLAG){
        Cleanup( );
        exit(1);
    }
    strcpy(Nodes[ReservedNode].Key, Key);
    strcpy(Nodes[ReservedNode].Data, Data);
    _os_sema_p(&Header→Lock);
    Nodes[ReservedNode].Next = Header→First;
    Header→First = ReservedNode;
    _os_sema_v(&Header→Lock);
    ReservedNode = FLAG;
}


static boolean FindFreeNode( )
{
    _os_sema_p(&Header→Lock);
    if(Header→Freelist == FLAG){
        _os_sema_v(&Header→Lock);
        return FALSE;
    }else {
        ReservedNode = Header→Freelist;
        Header→Freelist = Nodes[Header→Freelist].Next;
        _os_sema_v(&Header→Lock);
        return TRUE;
    }
}
```

```
static NodeIndex FoundNode=FLAG;
static NodeIndex FoundPrev=FLAG;
Semaphore FoundLock[2] = {NULL,NULL};

static boolean FindEntry(char *Key)
{
    NodeIndex i, Trailer=FLAG;
    Semaphore LastLock=&Header→Lock;

    _os_sema_p(LastLock);
     i = Header→First;
    while(i != FLAG){
        _os_sema_p(&Nodes[i].Lock);
         if(strcmp(Key, Nodes[i].Key) == 0){
            FoundNode = i;
            FoundPrev = Trailer;
            FoundLock[0] = LastLock;
            FoundLock[1] = &Nodes[i].Lock;
            /*
                Return with locks on the found node and the node before it.
            */
            return TRUE;
        }
        _os_sema_v(LastLock);
         LastLock = &Nodes[i].Lock;
        Trailer = i;
        i = Nodes[i].Next;
    }
    _os_sema_v(LastLock);
     return FALSE;
}


static void Delete( )
{
    Nodes[FoundPrev].Next = Nodes[FoundNode].Next;
    if(FoundLock[0] != &Header→Lock)
        _os_sema_p(&Header→Lock);
     Nodes[FoundNode].Next = Header→Freelist;
    Header→Freelist = FoundNode;
    if(FoundLock[0] != &Header→Lock)
        _os_sema_v(&Header→Lock);
    _os_sema_v(FoundLock[0]);
     _os_sema_v(FoundLock[1]);
}
```

```
static void Usage()
{
    static char const * const msg[] = {
        "indcard [-l] [-d] [-a] [-?]",
        "\t -l \tList the contents of the card file",
        "\t -a \tAdd a record to the card file",
        "\t -d \tDelete a record from the card file",
    NULL};
    char **ptr;

    for(ptr = (char **)msg; *ptr != '\0'; ++ptr)
        printf("%s\n", *ptr);
}
```

Indcard looks for a data module. If it does not find it, it creates one. This data module is used to store a simple multi-user database. It has three operations: add, delete, and list. The operation is selected with a command-line option. The rest of the utility's operation is interactive.

The main point of indcard is the way it locks each record while it uses it. Provided that all programs follow the same locking protocol when they access the shared database, the locks will prevent each program from updating the database under another program.

A single lock for the entire database would have been perfectly satisfactory for this application. ***Indcard*** uses fine-granularity locking just to show how it is done.

12.2 Basic Extensions

The semaphore library routines fit the most popular uses of binary semaphores, but the code can be optimized for special purposes or twisted into new shapes.

The simplest optimization of semaphores is to remove the test for a processor that supports `cas`. That test has to be in the library because code created for 68000's must run on any processor. `Cas` is only present on processors starting with the 68020, so it cannot be used on processors like the 68000 and 68010. `Cas` has to be used on at least the 68040 because the algorithm doesn't seem to work without it. This incompatibility forces library code to test for processor type, but if you write code that will run on a known processor, the code can be made processor-specific.

12.2.1 Polling a Semaphore

Sometimes a program will want to acquire a lock if the resource is free, but be unwilling to wait for the lock. This requires a version of _os_sema_p() that returns an error immediately when the semaphore is busy, and never blocks.

```
                        nam     poll.a
                        ttl     Non-blocking reserve-semaphore function
                        use     <oskdefs.d>
                        opt     -l
                        psect   poll,0,0,0,32,0
00000000                align   4
00000000                org     0
00000000  Lock          do.l    1

          *
          * error_code _os_sema_poll(void *semaphore)
          * Return immediately with or without the semaphore
          *
0000 c188 _os_sema_poll: exg.l d0,a0            put semaphore pointer in a0
 0002=52a8              addq.l  #1,s_lock(a0)   Play by the rules
0006=4ae8               tas     s_value(a0)     Try to claim the semaphore
000a 6606               bne.b   NoGo            Can't? leave
000c c188               exg.l   d0,a0
000e 7000               moveq   #0,d0           SUCCESS
0010 4e75               rts
0012=53a8 NoGo          subq.l  #1,s_lock(a0)
0016 c188               exg.l   d0,a0
0018 7001               moveq   #1,d0           Not SUCCESS
001a 4e75               rts
0000001c                ends
```

It looks like this code could be optimized a little by removing the `addq` instruction. That would work correctly until another process used an ordinary _os_sema_p() function that waited behind a process that acquired the lock with _os_sema_poll(). The counter would indicate that no process was waiting, and the waiting process would continue waiting after the first process V()'d the semaphore.

12.3 Advanced Extensions

Semaphores can be extended beyond simple changes to the standard library code.

12.3.1 Readers/Writers

Readers/writers locking is a solution for many applications that have two classes of use for a resource. The reading class is happy to share the resource with any number of other readers, but is not willing to share with any writers. Processes using the writing class of access won't share with anyone.

The readers/writers lock requires two semaphores. The algorithm for write locks simply locks the write semaphore. Read locks use a "last one out please turn off the lights" trick. The reader's lock protocol counts the number of readers using the resource. The first reader in (count of 1) P( )'s the write lock. That P( ) operation blocks until there is no writer using the resource, then locks writers out. The reader's exit protocol decrements the reader count. When the last reader finishes, the exit protocol V( )'s the write lock.

The only thing wrong with this implementation of readers/writers is that it uses quite a lot of memory, 100 bytes per lock.

```
#include "rwlock.h"
#include <errno.h>
#include <const.h>

error_code Read_lock(RWSemaphore locks)
{

    if((errno = _os_sema_p(&locks→mutex)) != SUCCESS)
        return errno;
    ++locks→readct;
    /*
        If this is the first reader we need to wait for writers to clear out, then
        close the door on them.
    */
    if(locks→readct == 1){/*lock out writers */
        if((errno = _os_sema_p(&locks→write)) != SUCCESS){
            _os_sema_v(&locks→mutex);
             return errno;
        }
    }
    errno = _os_sema_v(&locks→mutex);
    return errno;
}


error_code Read_unlock(RWSemaphore locks)
{
    if((errno = _os_sema_p(&locks→mutex)) != SUCCESS)
        return errno;
    locks→readct−−;
    /*If this is the last reader, let the writers in */
    if(locks→readct == 0){/*release writers */
        if((errno = _os_sema_v(&locks→write)) != SUCCESS){
             _os_sema_v(&locks→mutex);
            return errno;
        }
    }
    errno = _os_sema_v(&locks→mutex);
    return errno;
}


error_code Write_lock(RWSemaphore locks)
{
    return _os_sema_p(&locks→write);
}


error_code Write_unlock(RWSemaphore locks)
{
    return _os_sema_v(&locks→write);
}


void InitRW_Sema(RWSemaphore locks)
{
    _os_sema_init(&locks→mutex);
     _os_sema_init(&locks→write);
}
```

A program that demonstrates readers/writers locking is in section 12.4.3. To see it work, make testrw, then start several of them:

```
testrw & testrw & testrw &  testrw & testrw
```

The test program detects lock violations. It also reports each read and write entry into the lock.

12.3.2 Semaphore "Lite"

Complex data structures (like the index card linked list in section 12.1.7) may use many semaphores. The memory consumption can get out of hand, but it can often be controlled by enhancing the binary semaphore library. Provided that the locks have light contention, many locks can be loaded onto one semaphore. Each lock needs enough memory for a counter than can span the maximum number of processes that might wait for that lock plus one bit. The whole community of locks uses a common semaphore.

Any process that must wait for a lock marks the lock, then waits for the semaphore. This calls for two bits of trickery.

1. Since we never P() the semaphore unless we really want to wait, we have to initialize the semaphore to look like a process has already P()'d it.

2. When a process V()'s one of the locks, it needs to know whether that V() needs to release a process waiting in the semaphore. Then it needs to release the *right* process waiting for the semaphore.

   There is no official way for a V() to activate a particular process waiting at the semaphore. The cleanest way to do this is to let the waiting processes select themselves. The V() points the user field in the semaphore data structure at the lock it means to release, then releases the semaphore. The process that wakes up checks the value in s_user. If s_user does not point to that process' lock, the process V()'s the semaphore to release another process, sleeps a tick to let another process claim the semaphore, and P()'s the semaphore to wait again. This process rattles activation down the list of processes waiting for locks attached to the semaphore until the right one wakes up.

When this locking strategy is used appropriately,[4] there will seldom be processes waiting on the semaphore. If the queue builds up, performance degrades. Even a process V()ing a semaphore is penalized, since the V() code checks to see whether another V() is still looking for its target lock and loops until s_user contains a zero (indicating that the last V() reached its target).

```
                     nam      lite_sema_p
                     ttl      lite_sema_p – Memory-efficient Semaphore
                     psect    lite_sema_p,0,0,0,0,0
          *
          * lite_sema_p(Semaphore master, u_int16 *slave)
          *
0000 c388 lite_sema_p: exg.l  d1,a0
0002 5250            addq.w   #1,(a0)
0004 4ad0            tas.b    (a0)
0006 6604            bne.b    DoHeavyP
0008 c388            exg.l    d1,a0
000a 6022            bra.b    CmnX2

000c 2f01  DoHeavyP  move.l   d1,–(sp)         this is really a0
000e 2f08            move.l   a0,–(sp)         save slave pointer
0010 2040            move.l   d0,a0            point to master semaphore
0012 7201  P_Retry   moveq    #1,d1            P operation
0014=4ae8            tas      s_value(a0)      make sure the locked bit is set
0018=4e40            os9      F$Sema           queue up
 001c 2217           move.l   (sp),d1          get the slave lock pointer
001e=b2a8            cmp.l    s_user(a0),d1    is the master ours?
```

[4] Locks that share a semaphore should only be used when contention is expected to be light.

```
0022 660e               bne.b    P_Again          no: pass it on
0024 7000               moveq    #0,d0            SUCCESS (and clear reserved)
0026=2140               move.l   d0,s_user(a0)
002a 588f               addq.l   #4,sp
002c 205f  CmnX         move.l   (sp)+,a0
002e 7000  CmnX2        moveq    #0,d0            SUCCESS
0030 4e75               rts
0032 7202 P_Again       moveq    #2,d1            V operation
0034=4e40               os9      F$Sema
 0038 7001              moveq    #1,d0
003a=4e40               os9      F$Sleep          sleep a tick to prevent us from just P'ing on the fast track
 003e 2008              move.l   a0,d0            put master pointer in d0 for F$Sema SVC
0040 60d0               bra.b    P_Retry          and wait again.
                        ttl      lite_sema_v
0042 48e7 lite_sema_v: movem.l d0/a0,−(sp)
0046 2041               move.l   d1,a0
0048 103c               move.b   #$80,d0
004c 7200               moveq    #0,d1
004e 0ad0               cas.b    d0,d1,(a0)       release lock (non-cacheable)
0052 5350               subq.w   #1,(a0)          uncount the process that had the lock
0054 6604               bne.b    Heavy_V          noone waiting, don't bother the master semaphore
0056 588f               addq.l   #4,sp            clear d0 off stack
0058 60d2               bra.b    CmnX

005a 205f  Heavy_V      move.l   (sp)+,a0         now address master semaphore
005c 2008               move.l   a0,d0            and get it ready for F$Sema
005e=4aa8  WLoop        tst.l    s_user(a0)
0062 660c               bne.b    Re_V
0064=2141               move.l   d1,s_user(a0)
0068 7202               moveq    #2,d1            V operation
006a=4e40               os9      F$Sema           (d0 is sema pointer, d1 is 2)
 006e 60bc              bra.b    CmnX

0070 7001 Re_V          moveq    #1,d0
0072=4e40               os9      F$Sleep          sleep a tick
0076 60e6               bra.b    WLoop
                        ttl      lite_sema_init
           *
           * void lite_sema_init(Semaphore master, u_int16 *slave);
           *
0078 48e7 lite_sema_init: movem.l d0/d1/a0,−(sp)
007c 4a80               tst.l    d0
007e 6714               beq.b    nomaster
0080=6100               bsr      _os_sema_init    in case
0084 2057               move.l   (sp),a0
           * prime the master so it will wait on the first P
0086=4ae8               tas      s_value(a0)
008a 7000               moveq    #0,d0
008c 7201               moveq    #1,d1
```

```
008e=0ee8                cas.l    d0,d1,s_lock(a0)  increment counter in a mp safe way
0094 206f  nomaster      move.l   4(sp),a0
0098 30bc                move.w   #0,(a0)           clear the slave
009c 508f                addq.l   #8,sp             clear d1 and d0 off the stack
009e 608c                bra.b    CmnX
000000a0                 ends
```

A program that exercises lite semaphores is at the end of this chapter in section 12.4.1.

12.3.3 Interrupt Service Routines

Semaphores are the fastest way for an interrupt service routine to release a waiting process.

Here's a chunk of code that uses most of the easy tricks to get an interrupt service routine to wake up a process fast. Two tricks need careful warnings:

Trick One It uses F$FIRQ to cut interrupt response time. This call cuts the overhead in the interrupt prolog, but it has strict rules.

- The interrupt service routine must leave all registers except d0 and a2 with the same values it gets them.
- Only one FIRQ is allowed per vector.

Trick Two It uses OS9svc to remove the system call overhead from the F$Sema call. For calls from system state the OS9svc macro bypasses all the SVC overhead and goes directly to the kernel code that services the SVC.

This works easily for a few SVCs. F$Send, F$Sleep, and F$Sema's V operation are some important ones.[5] Any use of OS9svc beyond sending a wakeup signal and sleeping without a time limit may not be wise. On those two services OS9svc is sufficiently established to have some measure of security by historic precedent. Beyond those, efficient use of OS9svc depends on undocumented interfaces within the kernel which are subject to unannounced change. This means that OS9svc should only be used with system calls installed in P2 modules under the programmer's control or in modules that can easily be updated each time the operating system is updated.

Any use of OS9svc can be replaced with an ordinary OS9 trap, except that the macro is 30 to 50 percent faster.

[5] OS9svc for a semaphore P operation is tricky, too tricky for this book.

This test program doesn't do anything useful. It is a system state process that attaches an interrupt service routine to one of the MVME167's timers and communicates from the interrupt service routine to the rest of the process with semaphores.[6]

SemII

Most of the interesting substance of the program is in the Firq_Svc routine.

```
                  nam      SemInts
                  ttl      Use Semaphores for sync with ISR
00000003 Edition  equ      3              Current Edition
         *
         * This is a simplified interrupt tester that V's a semaphore
         *
00000101 Type     set      (Prgrm<<8)+Objct
0000a000 AttrRevs set      ((ReEnt+SupStat)<<8)+0
00000800 Stack    set      2048
                  psect    clock_167,0,0,0,Stack,0
                  use      <oskdefs.d>
                  opt      -l
00000002 V_OP     equ      2
         *
         * Define the OS9svc macro
         *
         * Warning: This calls the SVC code directly.
         *        It can break the kernel terribly if it is not done
         *        exactly right. Generally, it is only safe for
         *        system calls that return no parameters and
         *        use few parameters.
         OS9svc   macro
                  ifne     \#-1 must have exactly one argument
                  fail     wrong number of arguments to OS9svc macro
                  endc
                  move.l   a3,-(a7) save reg
                  movea.l  D_SysDis(a6),a3 get system dispatch tbl ptr
                  pea      OS9svc\@(pc) set return address
                  move.l   \1+\1+\1+\1(a3),-(a7) set OS9 service routine ptr
                  movea.l  \1+\1+\1+\1+256*4(a3),a3 get service routine data ptr
                  rts      execute service routine
         OS9svc\@ movea.l  (a7)+,a3 restore reg
                  endm
```

[6] This program slips outside the scope of this book. The OS9svc macro is one of OS-9's "major mysteries." It deserves a chapter in a more advanced Insights, not a passing mention. The F$FIRQ SVC is in the same category. The magic that plays with standard I/O in the SysProc() function is Ultra C stuff.

```
              * hardware specific definitions (MVME167 to start with)
              *
              * NOTE: we use the same irq level as the ticker (which is on the
              * same vector - that way we don't have to cover problems in the
              * irq svc routine when irq(not-ticker) is interrupted by irq(ticker)
              *
00000006  HW_LEVEL equ    6                 hardware irq level to use
00000069  HW_VECT equ     $69               PCC Timer #1
fff42000  HW_ADDR equ     0xfff42000        PCC chip base address

00000004  T1_COMPARE equ 4                  compare register offset
00000008  T1_COUNT equ    8                 count register offset
00000014  T1_CTRL equ     $14               t1 control (low byte)
00000018  T1_IRQ    equ   $18               t1 status (low byte)

              * T1_CTRL defs
00000000  b_timen   equ   0                 timer enable bit
00000001  timen     equ   (1<<b_timen)
00000001  b_coc     equ   1                 clear-on-compare bit
00000002  coc       equ   (1<<b_coc)

              * T1_IRQ defs
              *
00000003  b_irq_clr equ   3                 interrupt clr
00000008  irq_clr   equ   (1<<b_irq_clr)
00000004  b_irq_en  equ   4                 interrupt enable
00000010  irq_en    equ   (1<<b_irq_en)
00000005  b_irq_pend equ  5                 interrupt pending
00000020  irq_pend  equ   (1<<b_irq_pend)

                    vsect
00000000  ClockRate: ds.l 1                 Clock rate in microseconds
00000000            ends

              *
              * FInitClock: install clock device onto F$FIRQ system
              *           and initialize clock
              *
              * passed: d0 = clock rate in microseconds
              *         (a6) = static storage ptr
              *
0000 48e7 finit:    movem.l d1/a0/a2,-(sp)
0004 2d40           move.l  d0,ClockRate(a6)

0008 244e           move.l  a6,a2         put static storage pointer where it belongs for FIRQ
000a 303c           move.w  #HW_VECT,d0   get vector to use

000e 7200           moveq.l #0,d1
0010 41fa           lea.l   Firq_Svc(pc),a0  get address of routine
```

```
0014=4e40           os9      F$FIRQ          install device
 0018 6408          bcc.s    fSetupHW        ..continue if installed ok
001a 2001           move.l   d1,d0           Put error code where C expects it
001c 4cdf           movem.l (sp)+,d1/a0/a2   restore regs
0020 4e75           rts

          *
          * Setup timer to service some interrupts
          *
          fSetupHW:
0022 612e           bsr.s    Init_HW         setup hardware to run
0024 7000           moveq.l #0,d0            signal all clear
0026 4cdf           movem.l (sp)+,d1/a0/a2   restore regs
002a 4e75           rts

          *
          * Remove device from F$FIRQ system
          *
002c 48e7 fterm:    movem.l d1/a0/a2,–(sp)
0030 6164           bsr.s    Term_HW         clobbers a0 and d0
0032 303c           move.w   #HW_VECT,d0 get vector used
0036 7200           moveq.l #0,d1            sweep reg clobbers d1
0038 91c8           suba.l   a0,a0           indicate removing from irq system
003a 244e           move.l   a6,a2           static storage pointer
003c=4e40           os9      F$FIRQ          remove it
 0040 6408          bcc.s    Term_OK         ..no error; return happy
0042 2001           move.l   d1,d0           put error where C expects it
0044 4cdf           movem.l (sp)+,d1/a0/a2
0048 4e75           rts
          *
          * clean exit, all tests passed
          *
004a 7000 Term_OK: moveq.l #0,d0             signal all clear
004c 4cdf           movem.l (sp)+,d1/a0/a2
0050 4e75           rts
                    ttl      MVME167-specific code
          ********************
          * These are Hardware specific for the MVME167
          *

          ********************
          * Init_HW: enable hardware interrupts
          *
          * Passed: (a6) = static storage ptr
          *          (a2) = same
          *
          Init_HW:
0052 207c           movea.l  #HW_ADDR,a0 get address of hardware
```

```
          *
          * stop the counter
          *
0058 2028           move.l  T1_CTRL(a0),d0get control reg
005c 0880           bclr.l  #b_timen,d0    clear counter enable
0060 2140           move.l  d0,T1_CTRL(a0)tell h/w
0064 4e71           nop                    sync with h/w
          *
          * disable pending irqs
          *
0066 2228           move.l  T1_IRQ(a0),d1  get h/w irq control
006a 4201           clr.b   d1             disable irqs/etc
006c 0001           ori.b   #irq_clr,d1    clear pending irqs
0070 2141           move.l  d1,T1_IRQ(a0)  tell h/w
0074 4e71           nop                    sync with h/w
          *
          * set timer count period
          *
0076 216e           move.l  ClockRate(a6),T1_COMPARE(a0) set h/w count compare period
007c 217c           move.l  #0,T1_COUNT(a0) init count register
          *
          * enable counter and counter irqs
          *
0084 0001           ori.b   #HW_LEVEL+irq_en,d1 set irq h/w/level, enable irqs
0088 0000           ori.b   #timen+coc,d0  enable timer, set clear-on-compare
008c 2140           move.l  d0,T1_CTRL(a0)set counter running
0090 2141           move.l  d1,T1_IRQ(a0)  enable interrupts
0094 4e75           rts
          Term_HW:
          *
          * disable further irqs
          *
0096 207c           movea.l #HW_ADDR,a0 get h/w address
009c 2028           move.l  T1_CTRL(a0),d0get timer control
00a0 4200           clr.b   d0             clear enables
00a2 2140           move.l  d0,T1_CTRL(a0)tell timer to stop
00a6 4e71           nop                    sync hardware
00a8 2028           move.l  T1_IRQ(a0),d0  get irq control
00ac 4200           clr.b   d0             clear off irq controls
00ae 0000           ori.b   #irq_clr,d0    clear pending irqs
00b2 2140           move.l  d0,T1_IRQ(a0)  disable interrupts
00b6 4e71           nop                    sync h/w
00b8 4e75           rts
                    ttl     ISR
          ********************
          * Firq_Svc: service timer via F$FIRQ system
          *
```

```
               * Passed:  d0.w = vector offset
               *          (a2) = static storage ptr
               *          (a6) = system global data ptr
               *
               * Only d0/a2 may be destroyed.  All others MUST be preserved.
               *
               *
               ** NOTE - the 167's ticker is also on the same vector, thus we need
               **          to be very careful about how we validate the interrupt source.
               *
               *
               * check that interrupt is really pending
               *
00ba 48e7  Firq_Svc:  movem.l d1/d2/a0/a5,-(a7) MUST be saved
00be 207c             movea.l #HW_ADDR,a0  get base address of hardware
00c4 2228             move.l  T1_IRQ(a0),d1   read irq control
00c8 0801             btst.l  #b_irq_pend,d1  interrupt truely pending?
00cc 660a             bne.s   Firq_20         ..yes; continue
00ce 4cdf             movem.l (a7)+,d1/d2/a0/a5 restore registers
00d2=003c             ori.b   #Carry,ccr      signal further polling required
00d6 4e75             rts

00d8 08c1  Firq_20:   bset.l  #b_irq_clr,d1   set "clear irq flag"
00dc 2141             move.l  d1,T1_IRQ(a0)   tell h/w
00e0=41ea             lea.l   active_semaphore(a2),a0

00e4=4228             clr.b   s_value(a0)     clear lock
               *
               * Use MP-safe protocol (just for fun)
               *
00e8=2028 cas_loop    move.l  s_lock(a0),d0   get lock count (use count)
00ec 2200             move.l  d0,d1           copy count
00ee 5381             subq.l  #1,d1           decrement lock count (use count)
00f0=0ee8             cas.l   d0,d1,s_lock(a0) compare and swap lock count
00f6 66f0             bne.b   cas_loop        bra if value changed behind our back
00f8 5380             subq.l  #1,d0           perform operation again to set condition codes
00fa 6722             beq.b   Firq_X          bra if semaphore not in use
00fc 6a06             bpl.b   Sem_SVC         bra if semaphore still in use
               * We shouldn't have this case
00fe=52a8             addq.l  #1,s_lock(a0)   restore positive lock count
0102 601a             bra.b   Firq_X
00000104  Sem_SVC     equ     *
0104 7202             moveq.l #V_OP,d1        flag V operation
0106 2008             move.l  a0,d0           SVC Pointer
                      OS9svc  F$Sema
               * There'd better be no error

011e 207c  Firq_X     move.l  #HW_ADDR,a0
```

```
0124 216a          move.l   ClockRate(a2),T1_COMPARE(a0) set h/w count compare period
012a 217c          move.l   #0,T1_COUNT(a0) init count register
0132 4cdf          movem.l (a7)+,d1/d2/a0/a5 restore regs
0136 7000          moveq.l #0,d0            clear carry (no further polling required)
0138 4e75          rts                      return to kernel
0000013a           ends
```

SemInt

The driver for the low-level code is written in C. After it does initial housekeeping to set it up as a well-behaved system process the code simply calls _os_sema_p( ) a number of times to let the interrupt service routine V it.

```
#include <stdio.h>
#include <errno.h>
#include <modes.h>
#include <process.h>
#include <sysglob.h>
#include <setsys.h>
#include <setjmp.h>
#include <signal.h>
#include <semaphore.h>
#include <const.h>

#define SEM_LIMIT               100     /*interrupts */
#define DEFAULT_INTERVAL        500     /*500 us */

#define TRUE    1
#define FALSE   0

typedef int boolean;

_asm("_sysattr: equ $a001");          /*System state process */

void ProcessArgs(int , char **);
void Test(u_int32);
void SysProc(void);
void Banner(char *, Semaphore, u_int32, u_int32, boolean);

semaphore active_semaphore;

main(int argc, char **argv)
{
    u_int32 TickRate=DEFAULT_INTERVAL;
    SysProc();
    ProcessArgs(argc−1, argv+1);
    _os_sema_init(&active_semaphore);
     Test(TickRate);
    _os_sema_term(&active_semaphore);
     fclose(stdin);
    fclose(stdout);
    fclose(stderr);
    exit(0);
}


void SysProc()
{
const owner_id SuperUser = {0};
    register procid *prc = sysglob(Pr_desc, D_Proc);

    _os_setuid(SuperUser); /*set to super user */
     /*fix up stdio for system state process */
    stdin→_fd = prc→_path[0];
    _from_new(stdin);
    stdout→_fd = prc→_path[1];
    _from_new(stdout);
    stderr→_fd = prc→_path[2];
    _from_new(stderr);
}


void Util()
{
    static char *UtilStr[] = {
        "semint_167",
        "Demonstrate a semaphore from an ISR",
    NULL};
    char **ptr;

    for(ptr = UtilStr; *ptr != NULL; ++ptr)
    fprintf(stderr, "%s\n", *ptr);
}


void ProcessArgs(int argc, char **argv)
{
    char *ptr;
    for(;argc >0; argc––, ++argv){
        ptr = *argv;
        if(*ptr == '-')
        for(++ptr; *ptr != '\0'; ++ptr)
        switch(*ptr){
            case '?':
            default:
                Util();
                exit(0);
        }/*switch end */
        else{
            Util();
            exit(1);
        }
    }/*for end */
}


void Test(u_int32 TickRate)
{
    int err;
    u_int32 ct;

    if((err = finit(TickRate)) != 0)
        exit(err);
    for(ct = 0; ct < SEM_LIMIT; ++ct)
        _os_sema_p(&active_semaphore);
     fterm();
    printf("Caught %d interrupts/semaphores\n", ct);
}
```

SemInt must be made and run by a super user, but since it is just a system state process it can be run with no special measures. It will start, be silent briefly, then announce how many times the semaphore was V'd.

12.4 Test Programs and Makefiles

12.4.1 Lite-Lock Makefile and Test Program

```
–b
test_ls: test_ls.r lite_sema_pv.r
    cc –g –tp020c test_ls.r lite_sema_pv.r –f=test.ls
```

```
test_ls.r: test_ls.c
    cc –tp020c –g –eas test_ls.c

lite_sema_pv.r: lite_sema_pv.a
    r68 –m4 lite_sema_pv.a –o=lite_sema_pv.r
```

Test Program

```
#include <stdio.h>
#include <module.h>
#include <errno.h>
#include <semaphore.h>
#include <const.h>

#define SLAVE_COUNT         10
#define LOCKS               "Test_ls_locks"
#define DEFAULT_SLEEP       30
#define INTER_V_TIME        5

typedef u_char Slave_Index;

typedef struct {
    semaphore Master;
    u_int16 Slaves[SLAVE_COUNT];
}Lock_Structure;


static u_int32 sleep_seconds = DEFAULT_SLEEP;
static Semaphore Lock_Master;
static mh_com * LockMod_header;
static u_int16 *Lock_Slaves;

static Slave_Index lock_ct=0;
static Slave_Index lock_array[SLAVE_COUNT];

/*Prototypes */
extern error_codelite_sema_init(Semaphore, u_int16 *);
extern error_code lite_sema_p(Semaphore, u_int16 *);
extern error_code lite_sema_v(Semaphore, u_int16 *);
static void Usage(void);
static error_code MkMultisem(char *);
static int Process_Args(int, char **);
static void Reserve_and_release(void);
static void Init_ms(Lock_Structure *);
static void Cleanup(void);

main(int argc, char **argv)
{
    if(Process_Args(argc, argv) == 0)
        exit(0);
    MkMultisem(LOCKS);
    Reserve_and_release( );
    Cleanup( );
    exit(0);
}


static void Reserve_and_release( )
{
    u_int32 Sleep_time;
    Slave_Index i;

    for(i=0; i < lock_ct; ++i)
        lite_sema_p(Lock_Master, Lock_Slaves + lock_array[i]);

    printf("Locks done:");
    for(i=0; i < lock_ct; ++i) printf(" %d", lock_array[i]);
    putchar('\n');

    Sleep_time = 0x80000000 | (sleep_seconds * 256);
    _os9_sleep(&Sleep_time);

    for(i=0; i < lock_ct; ++i){
        lite_sema_v(Lock_Master, Lock_Slaves+ lock_array[i]);
         printf("Unlocked %d\n", lock_array[i]);
        Sleep_time = 0x80000000 | (INTER_V_TIME * 256);
        _os9_sleep(&Sleep_time);
    }
}


static error_code MkMultisem(char *name)
{
    mh_com *head;
    Lock_Structure *data;
    const u_int16 datasize = sizeof(Lock_Structure);
    u_int16 TypeLang=mktypelang(MT_DATA,ML_ANY);
    u_int16 AttrRev=0;
    if((errno = _os_link(&name, &head, (void **)&data, &TypeLang, &AttrRev)) != SUCCESS){
        AttrRev = mkattrevs(MA_REENT, 1);
        if((errno = _os_mkmodule(name, datasize, &AttrRev, &TypeLang,
                MP_OWNER_READ | MP_OWNER_WRITE |
                MP_GROUP_READ | MP_GROUP_WRITE |
                MP_WORLD_READ | MP_WORLD_WRITE,
                (void **)&data, &head, 0)) == SUCCESS){
            /*Extra link to hold the module in memory */
            (void)_os_link(&name, &head, (void **)&data, &TypeLang, &AttrRev);
            Init_ms(data);
        }else
            return errno;
    }
    LockMod_header = head;
    Lock_Master = &data->Master;
    Lock_Slaves = data->Slaves;
    return SUCCESS;
}


static void Cleanup( )
{
    _os_unlink(LockMod_header);
}


static void Init_ms(Lock_Structure *data)
{
    Slave_Index i;

    for(i=0;i<SLAVE_COUNT; ++i)
        lite_sema_init(&data->Master, data->Slaves + i);
 }


static int Process_Args(int argc, char **argv)
{
    char *ptr;

    for(argc--, argv++; argc != 0; argc--, ++argv)
        if(**argv == '-')
            for(ptr = *argv+1; *ptr != '\0' ; ++ptr)
                switch(*ptr){
                    case 't':
                    case 'T':
```

```
                    sleep_seconds = atoi(ptr+1);
                    ptr = " ";
                    break;
                case '?':
                default:
                    Usage( );
                    return 0;
            }
    else
    lock_array[lock_ct++] = atoi(*argv);
    return lock_ct;
}


static void Usage( )
{
    static char const * const msg[ ] = {
    "test_ls [-?]  [-t<s>] {<n> <n> ...}",
        " \t-t \tHold the lock for this many seconds",
        " \tLock slave resources <n> for <s> seconds",
        " \tIf multiple resources are locked, they will",
        " \tbe released at 5 second intervals.",
    NULL};
    char **ptr;

    for(ptr = (char **)msg; *ptr != '\0'; ++ptr)
        printf("%s\n", *ptr);
}
```

12.4.2 Interrupt Service Routine Makefile

```
–b
semint_167: semint.r semll.r
    cc –olg –tp020 semint.r semll.r –l=../lib/semaphore.l –f=semint_167
    attr –penpr –x semint_167
    chown 0.0 /h0/cmds/peter/semint_167
    fixmod –uo=0.0 –ua=a001 –x semint_167
    attr –prpe –x semint_167

semint.r: semint.c
    cc –eas –tp020c semint.c

semll.r: semll.a
    r68 –m4 semll.a –o=semll.r
```

12.4.3 Readers/Writers Makefile and Test Program

```
–b
TMP      =  /r0
LFLAGS =  –g
CFLAGS =  –g –tp020c –td$(TMP) –eas
testrw: testrw.r rw.r
    cc $(LFLAGS) testrw.r rw.r –f=testrw

testrw.r: testrw.c rwlock.h
    cc $(CFLAGS) testrw.c

rw.r: rw.c
    cc $(CFLAGS) rw.c
```

Test Program

```
#include <stdio.h>
#include <module.h>
#include <process.h>
#include <errno.h>
#include <const.h>
#include "rwlock.h"

#define DATA_NAME                  "RW.MODULE"

#define ITERATIONS                       20
#define READS_PER_ITERATION        50
#define WRITES_PER_ITERATION       2
#define READ_HOLD                        (0x80000000 | 1)
#define WRITE_HOLD                       (0x80000000 | 2)

typedef struct {
    rwsemaphore rwsema;
    u_int32 data;
}shared_data, *Shared_data;


static RWSemaphore RWLock;
static u_int32 * volatile sdata;
static mh_com *data_Head;
static process_id pid;
```

```
/*Prototypes */
static void ProcessArgs(int argc, char **argv);
static error_code FindData(char *name);
static void Work(u_int32, u_int32);
static void Cleanup(void);
static void waste_time(void);
static void Make_Clean(char *);
static void Usage(void);

main(int argc, char **argv)
{
    u_int16 i;
    u_int16 dummy;

    ProcessArgs(argc–1, argv+1);
    (void)_os9_id(&pid, &dummy, &dummy, &dummy);
     if(FindData(DATA_NAME) != SUCCESS){
        perror("finding data module");
        exit(errno);
    }

    for(i=0; i < ITERATIONS; ++i)
        Work(READS_PER_ITERATION, WRITES_PER_ITERATION);
    Cleanup( );
    exit(0);
}




static void ProcessArgs(int argc, char **argv)
{
    char *ptr;
    for(;argc >0; argc––, ++argv){
        if(**argv == '-'){
            for(ptr = *argv+1; *ptr != '\0'; ++ptr){
                switch(*ptr){
                    case 'c':
                    case 'C':
                        Make_Clean(DATA_NAME);
                        exit(0);
                    case '?':
                    default:
                        Usage( );
                    break;
                }
            }
        }
    }
}

static void Work(u_int32 r, u_int32 w)
{
    u_int16 i;

    for(i = 0; i < r; ++i){
        _os_sigmask(1);
         Read_lock(RWLock);
        /*do something useful  */
        if(*sdata >= 2)
            fprintf(stderr, "Violation.  Reader/writer conflict %u %u\n",
                    pid, *sdata);
        *sdata = 1;
        waste_time( );
        *sdata = 0;
        Read_unlock(RWLock);
        _os_sigmask(−1);
        printf("%u read\n", pid);
    }
    for(i = 0; i < w; ++i){
        _os_sigmask(1);
         Write_lock(RWLock);
        /*do something useful  */
        if(*sdata >= 2)
            fprintf(stderr, "Violation.  Writer/writer conflict %u %u\n",
                    pid, *sdata);
        *sdata = 2;
        waste_time( );
        *sdata = 0;
        Write_unlock(RWLock);
        _os_sigmask(−1);
        printf("%u write\n", pid);
    }
}


static error_code FindData(char *name)
{
    mh_com *head;
    Shared_data data;
    const u_int16 datasize = sizeof(shared_data);
    u_int16 TypeLang=mktypelang(MT_DATA,ML_ANY);
    u_int16 AttrRev=0;

    if((errno = _os_link(&name, &head, (void **)&data, &TypeLang, &AttrRev)) != SUCCESS){
        AttrRev = mkattrevs(MA_REENT, 1);
        if((errno = _os_mkmodule(name, datasize, &AttrRev, &TypeLang,
                MP_OWNER_READ | MP_OWNER_WRITE |
                MP_GROUP_READ | MP_GROUP_WRITE |
                MP_WORLD_READ | MP_WORLD_WRITE,
                (void **)&data, &head, 0)) == SUCCESS){
            InitRW_Sema(&data->rwsema);
        }else
            return errno;
    }
    data_Head = head;
    RWLock = &data->rwsema;
    sdata = &data->data;
    return SUCCESS;
}


static void waste_time()
{
    int i,j;
    for(i=0;i<5000;++i)
        for(j=0;j<100;++j);
}

static void Cleanup()
{
    (void)_os_unlink(data_Head);
}


static void Make_Clean(char *name)
{
    const u_int16 TypeLang=mktypelang(MT_DATA,ML_ANY);

    while(_os_unload(name, TypeLang) == SUCCESS);
 }

static void Usage()
{
    static char const * const msg[] = {
        "testrw [-?] [-c]",
        "\tTest readers/writers locking",
        "\t -? \tGet this message",
        "\t -c \tClean up (unlink the data module)",
    NULL};
    char **ptr;
    for(ptr = (char **)msg; *ptr != NULL; ++ptr)
        printf("%s\n", *ptr);
}
```

Chapter 13

Summary of Interprocess Communication

OS-9 supports at least four separate mechanisms for interprocess communication. This chapter compares their strengths and weaknesses.

The four primary interprocess communication mechanisms supported by OS-9 are:

1. Binary semaphores
2. Events
3. Signals
4. Pipes and other communication through file managers.

There are other communication mechanisms, like spin locks, that are available but are not supported by the kernel.

13.1 Binary Semaphores

This is the fastest kernel-supported mechanism for locking. It efficiently locks data structures in shared data modules or shared system data structures. It also provides a simple suspend/release mechanism for interrupt service routines.

Semaphores are fast and simple, perfect for implementing locks. Since the library code supporting semaphores prevents a system call altogether unless there is contention, semaphores are an especially good choice when contention is light.

Strengths	Weaknesses
Fast	Few features
	SSM overhead when supported
	Setup overhead

If the target OS is the full kernel with SSM and contention for the lock will be heavy, events are a better choice than semaphores.

13.2 Events

In almost every case, if an application needs something like binary semaphores but more powerful, events are the right mechanism.

Semaphores are usually faster than events, so events should be used only when they are needed.

Events have a 32-bit value. This value lets events transfer data as well as perform synchronization.

Strengths	Weaknesses
Many features	slower
Easy to use	

13.3 Signals

Signals are the only mechanism for causing *asynchronous* activity in user-state code. Neither semaphores nor events have a way to activate a process that is not waiting. They are *synchronous* communication mechanisms. Signals will cause activity in the target process whether it is waiting or not.

Signals are about as fast as events. Whether they are more powerful or less powerful is open to debate. They are too different to compare easily.

From an embedded system's point of view the beauty of signals is that they provide a software analog to interrupts.

Strengths	Weaknesses
Model interrupts well	slower
Async	

13.4 Pipes

Pipes are quite different from the preceding mechanism. Mainly, events and signals carry at most 32 bits of data with their activation. A pipe can carry any amount of data.

If the goal is to carry a simple flow of data between two processes, pipes are a good choice since they combine data transport and synchronization. For more complicated situations a buffer pool stored in a shared data module and controlled with semaphore locks is faster and more versatile than communication through pipes, but this technique should be reserved for situations that require it. Compared to communication through pipes, the use of data modules is error prone. Simplicity is the greatest advantage of pipes.

Strengths	Weaknesses
Carry data	slower
Use I/O operations	requires IOMan and Pipeman
Simplicity	

Chapter 14

Traps

Trap handler support is a tool for late binding and modular programming. Trap handlers are similar in flavor to SVCs and subroutine modules.

A trap handler is rather like a subroutine module. To use trap handlers, a program selects the trap handler modules it wants to use and uses `trap` instructions to call functions in the trap handlers. Trap handlers are called with the same protocol used for SVCs except that while SVCs use `trap 0`, trap handlers are reached through the other fifteen traps. This chapter first illustrates access to the trap handlers supplied with OS-9. Then it discusses the construction of a small but complete trap handler module.

The standard trap handlers are mainly a memory conservation tool. The ***cio*** module handles all the C printf( ) and scanf( ) functions. Without cio, a C program with just one printf( ) in it includes about ten kilobytes of printf( ) support code. The next printf( ) only adds a few bytes, but the cost of the first one is important for small programs. With the ***cio*** trap handler, a program has to initialize a trap for ***cio*** (which takes about four instructions) and use a `trap` to call ***cio*** for each I/O function. Using ***cio***, the first printf( ) adds a few dozen bytes to a program instead of several kilobytes.

It is faster to call I/O functions from the C library than the ***cio*** trap handler. On a 20 Mhz 68020, calling and returning from a null trap handler takes about 22 µs, versus from 2.0 µs to 3.8 µs for a C function call depending on whether stack checking and floating-point coprocessor support are active. This is about an order of magnitude performance difference, but even this major difference is only noticeable for fast functions. Even just placing

```
register int x, y;
x = (25 * x + y);
```

Table 14.1: Performance of Trap vs. Function Call

Operation	Time in μs	
	Trap	Function
Null function	22	3
Trivial function	35	16

inside the null C function increased the benchmark time to between 15.2 μs and 17.0 μs for a function call and around 35 μs for the equivalent trap call.

The linker attaches library functions to the programs that use them. The program modules are bigger than they would be if they used traps to access the functions, but they can get at each function with a single `bsr` or `jsr` instruction. Traps are also accessed with a single instruction, a `trap` instruction. The `trap` invokes OS-9 which uses a string of instructions to transfer control to the trap handler.

The ***cio*** trap handler is a part of every OS-9 system. The utility programs use it and your programs can use it too, but unless you use C, it requires hard work. Probably more work than it is worth. ***Cio*** isn't documented in the *OS-9 Technical Manual,* so you have to figure it out from the source that comes with the C compiler.

The math trap handler (and the corresponding library) may be even more useful than ***cio***, and it *is* documented. It supports 57 functions related to numbers. It deals with 32-bit integers, 32-bit unsigned integers, single precision floating point numbers, double precision floating point numbers, and ASCII (printable) numbers. There's one function, `T$DNrm` (denormalize) that produces a 64-bit integer. Think about the amount of code you'd have to include in a program just to calculate the square root of two and reformat the floating point result into ascii (easily a thousand bytes), and you'll understand the motivation for the math trap handler.

14.1 Linking to a Trap Handler

Low-level `trap` instructions refer to a trap handler by number, but since the trap handler is a module, it is known to the system by an alphanumeric name. Before a process can invoke a trap handler, it must associate a number with the trap handler module. A program can select up to fifteen trap handlers and assign them trap numbers 1 through 15. It makes the selections with `F$TLink` SVC's. An `F$TLink` takes the name of a trap handler and the trap number you have chosen for it, and arranges things so next time you issue the selected trap, you reach that handler.

Trap handler modules can have static data associated with them. Each process that TLink's to the handler sets up a special block of static storage for that link. Each process descriptor has pointers to all the trap-handler static storage allocated by that process' F$TLink's.

You can include all F$TLink SVC's right at the beginning of a program—before they use any traps. There is, however, an alternative. If you use an uninitialized trap (a trap without a trap handler TLinked to it), OS-9 generates a special error. If there is an uninitialized trap exception vector, M$Excpt, in your program's module header, OS-9 calls some of your code instead of returning an error. It works something like a signal intercept.

Postponing making links to trap handlers isn't necessarily just procrastination. The F$TLink SVC takes some time. If you probably won't use a trap handler, you can save a little time by not linking to it. The exception handler can patch things up for you if you do use the trap. Another reason for making links to trap handlers only when you use them is that you can delay determining which handler to use until you actually need it. The exception routine gets the address of the unbound trap instruction, the trap number, the function code, and the contents of all the caller's registers. A program can use different trap handlers depending on where the trap is first used. That's not elegant, but it could be useful.

A simple use for deferred trap linkage is run-time support for high-level languages. It would be possible to have several versions of the code that sets up the run time environment for programs (e.g., cstart), but it is easier to have one version that sets up an uninitialized trap handler but initializes no traps. When a trap is used, the run-time support code does the required F$TLink. If no traps are used, no F$TLink's are done.

The following example sets up a link to the math trap handler, then quits. In a real program, this code would come before any traps were used.

```
                    nam    InitTraps
                    ttl    Initialize math trap before it is called
00000001 Edition    equ    1
00000101 Typ_Lang   equ    (Prgrm«8)+Objct
00008000 Attr_Rev   equ    (ReEnt«8)+0
00000100 StackSiz   equ    256
0000000d CR         equ    13              ASCII for carriage return
00000001 StdOut     equ    1               Standard Output path number
                    psect  InitTraps,Typ_Lang,Attr_Rev,Edition,
                           StackSiz,Entry
         * Collected strings and constants
         *
0000 6d61 MathName dc.b    "math",0
0005 556e BadMthL  dc.b    "Unsuccessful link to math",CR
0000001a BadMthLL equ      *–BadMthL
00000000 T$Math     equ    T$Math1         Use The Math1 code for math
00000020            align
         Entry
         *
         *                 Do TLink for Math
```

```
          * Put the standard trap number for math, T$Math (15), in D0,
          * and point to the trap handler module name, MathName (math), with
          * A0. We don't want to give math more static memory than its
          * default so we load D1 with 0.
          *
0020=7000           moveq   #T$Math,D0      Chosen trap number for math
0022 7200           moveq   #0,D1           No extra static storage
0024 41fa           lea     MathName(pc),A0 Point A0 at the name
0028=4e40           os9     F$TLink         Link to math as trap T$Math
002c 6410           bcc.s   Math_OK         Carry Clear: Continue
002e 3f01           move.w  D1,–(A7)        save error code
0030 7001           moveq   #StdOut,D0      Output path
0032 721a           moveq   #BadMthLL,D1    Length to write
0034 41fa           lea     BadMthL(pc),A0
0038=4e40           os9     I$WritLn        Write the message
003c 321f           move.w  (A7)+,D1
          Math_OK
          Exit
003e=4e40           os9     F$Exit
00000042            ends
```

The next program uses deferred TLink's and does something only a little less trivial than nothing at all. It converts the integers 10000 and 3 to double precision floating point and divides one by the other to get 3333.3333333. It converts that floating point number to a printable format and thrashes around inserting the decimal point where it belongs. Finally it prints the resulting string.

It demonstrates a way to handle several trap numbers with the same routine by checking for math2 traps as well as math1 traps. Math2 was a separate trap handler for transcendental functions that has been phased out. If the routine gets a math2 trap it generates an error (216, invalid path) because the trap handler "oldstuf" doesn't exist.

```
                    nam     InitTraps
                    ttl     Initialize math trap after it is called
00000001  Edition   equ     1
00000101  Typ_Lang  equ     (Prgrm«8)+Objct
00008000  Attr_Rev  equ     (ReEnt«8)+0
00000100  StackSiz  equ     256
0000000d  CR        equ     13              ASCII for carriage return
00000001  StdOut    equ     1               Standard Output path number
                    psect   PatchTraps,Typ_Lang,Attr_Rev,Edition,StackSiz,
                            Entry,TInit
                    vsect
00000000  DAccum    ds.l    2               Accumulator for doubles
00000008  Buffer    ds.b    15              Buffer for formatted output
00000000            ends
          *
```

```
              * Collected strings and constants
              *
0000 6d61 MathName dc.b      "math",0
0005 6f6c Math2Nam dc.b      "oldstuf",0
0000000e           align
              Entry
000e 203c          move.l   #3,D0
0014=4e40          tcall    T$Math1,T$LtoD Convert int to float
0018 2d40          move.l   D0,DAccum(A6) Save the result (3)
001c 2d41          move.l   D1,DAccum+4(A6) more saving
0020 203c          move.l   #10000,D0
0026=4e40          tcall    T$Math1,T$LtoD Convert int to float
 002a 242e         move.l   DAccum(A6),D2 Recover the 3 we saved
002e 262e          move.l   DAccum+4(A6),D3 Move the 3
0032=4e40          tcall    T$Math1,T$DDiv Figure 10000/3
0036 243c          move.l   #$0006000C,D2  12-digit #. 6 after '.'
003c 41ee          lea      Buffer(A6),A0
0040=4e40          tcall    T$Math1,T$DtoA Convert to printable form
              *
              * First find the closing null on the string
              *
0044 41ee          lea      Buffer(A6),A0     Beginning of string
0048 700b          moveq    #12–1,D0          Maximum possible length (minus 1)
              Search
004a 4a18          tst.b    (A0)+
004c 57c8          dbeq     D0,Search
              * Now A0 is pointing one past the null
              * We want to shift the last 6 digits of the number
              * right one byte to make room for a decimal point.
              * A0 already points to the end of the shift.
0050 43e8          lea      –1(A0),A1         Source
0054 7005          moveq    #6–1,D0           Set up to shift 6 times
              Shift
0056 1121          move.b   –(A1),–(A0)       Shift Buffer right one
0058 51c8          dbf      D0,Shift          Loop
005c 12bc          move.b   #'.',(A1)         Place decimal point
0060 137c          move.b   #CR,7(A1)         Close string with a CR
0066 7001          moveq    #StdOut,D0        Set output path
0068 720e          moveq    #14,D1            Length of buffer
006a 41ee          lea      Buffer(A6),A0     →String to output
006e=4e40          os9      I$WritLn
0072 7200          moveq    #0,D1             Return with no error
              Exit
0074=4e40          os9      F$Exit            and end
```

```
          *
          * Deal with uninitialized trap
          * First check the trap vector to discover whether it is for Math1
          * or Math2. Do the TLink for whichever it is.
          * Math2 is an antique—left over from old versions of OS-9—
          * but we use it anyway.
          *
          * To set up for a TLink:
          * Put the required trap number in D0, and point to the trap
          * handler module name with A0. We don't want to request memory
          * for the trap handlers beyond their defaults so we load D1 with 0.
          *
          *
          * The stack has the following information on it:
          *         8(SP)   caller's return address (4-byte)
          *         6(SP)   trap vector number (2-byte)
          *         4(SP)   function code (2-byte)
          *         0(SP)   caller's A6 register (4-byte)
          *
          * Except for SP (A7), which points to the stack frame above, the
          * registers are the caller's registers.
          *
          * We have no need for the caller's A6 register or the function code
          * so clear them off the stack.
          *
          TInit
0078 5c8f          addq.l  #6,SP            Toss some of the stack frame
007a 48e7          movem.lD0–D1/A0,–(SP) Save registers
0000000c  TVector  set     (3*4)            Offset from SP to vector
007e 302f          move.w  TVector(SP),D0   Get the vector
          *
          * The vector is an offset into a table of 4-byte entries.
          * The first user trap vector is at an offset of $80 from the
          * beginning of the table.
          * To get a trap number from the vector we subtract $80 from it
          * and shift the result right by two (dividing by four).
0082 907c          sub.w   #$80,D0          convert it to a trap #
0086 e440          asr.w   #2,D0
0088=b07c          cmp.w   #T$Math1,D0      Is this Math1?
008c 6608          bne.s   TryMath2
008e 41fa          lea     MathName(pc),A0 Address of handler name
0092 7200          moveq   #0,D1            No extra memory
0094 600c          bra.s   SetTrap
          TryMath2
0096=b07c          cmp.w   #T$Math2,D0      Is this Math2?
009a 6616          bne.s   TError
009c 41fa          lea     Math2Nam(pc),A0 Address of handler name
00a0 7200          moveq   #0,D1            no extra memory
          SetTrap
```

```
00a2=4e40            os9      F$TLink
00a6 65cc            bcs.s    Exit               Quit if error
00a8 4cdf            movem.l(SP)+,D0–D1/A0
00ac 548f            addq.l   #2,SP              Pop the vector off the stack
           *
           * Subtract four from the the return address so it will
           * return to the trap instruction that caused the error and re-execute it.
           *
00ae 5997            subq.l   #4,(SP)            Back the return address up
00b0 4e75            rts
           TError
00b2=7200            moveq    #E$ITrap,D1        set invalid trap # error
00b4 60be            bra.s    Exit
000000b6             ends
```

14.2 Writing a Trap Handler

Writing a trap handler isn't quite like writing a program. A trap handler's module header is more elaborate than a program's, and the trap handler's initial register values don't have the same meanings as a program's.

The module header for a trap handler contains all the fields from a program module's header, plus an initialization execution offset and a termination execution offset. A special rule in the linker causes the constants defined after the trap handler's main `psect` to be kept after the module header. Putting the two extra fields after the `psect` directive for the trap handler has the effect of adding them to the module header.

The following trap handler illustrates trap handler construction with most of the bells and whistles. It uses static storage and offers several different functions. It doesn't use the termination entry (which isn't supported by OS-9 yet).

This trap handler is called *Silly*—which describes its functions. It enhances the `F$Time` SVC by returning a string that comments on the time as well as the time in printable format. If you don't like the present time, it will format and add a comment to any time you give it.

It also provides random-number services in two forms. It can return the same type of text strings as the oracle (from the chapter on pipes), or simple random numbers.

Formatted time is returned by function code 1. It takes one argument, a pointer to a 25-byte space for the string, in A0.

Function code 2 formats a given time. It takes the time in D0 and a pointer to a 25-byte space in A0. It stores its result at A0.

Function code 3 returns an oracle response. It needs a pointer, in A0, to a 10-byte buffer for its answer.

Function code 4 returns a random integer in D0. It doesn't take any arguments.

```
                   nam     Silly
                   ttl     Entertaining Trap Handler
         mod       macro
                   divu    #\2,\1
                   lsr.l   #8,\1
                   lsr.l   #8,\1
                   endm

00000001 Ed        equ     1
00000b01 TypeLan   equ     (TrapLib«8)+Objct
00008000 Attr_Rev  equ     (ReEnt«8)+0
00000100 Stack     equ     256

00000001 SeedType  equ     1                  Julian without ticks
00000000 Gregorian equ     0                  Gregorian without ticks

         *
         * psect to define module header
         *
                   psect   Silly,TypeLan,Attr_Rev,Ed,Stack,Entry
0000 0000          dc.l    Init               Initialization entry point
0004 0000          dc.l    Term               Termination entry point

         *
         * Define the Trap handler's static storage
         *
                   vsect
00000000 Seed      ds.l    1                  Seed for random number generator
00000000           ends
         *
         * Trap init initializes the seed for the random number generator.
         * It is passed:
         *         d0:     The user trap number (2-byte)                  ignored
         *         d1:     Addition storage allocated (4-byte)            ignored
         *         d2-d7:  Caller's registers                             ignored
         *         a0:     End of trap handler module name ptr            ignored
         *         a1:     Trap handler execution entry point             ignored
         *         a2:     Trap handler module                            ignored
         *         a3-a5:  Caller's registers                             ignored
         *         a6:     Trap static storage base address
         *         a7:     Trap initialization stack frame
         * The stack frame contains:
         *         8(sp)   Caller's return PC (4-byte)
         *         4(sp)   contains nothing for 4 bytes.
         *         0(sp)   Caller's A6 register (4-byte)
         *
0008 48e7 Init     movem.l D0–D3,–(SP)        save registers
000c 7001          moveq   #SeedType,D0       type of time to use as seed
000e=4e40          os9     F$Time             get the current time
```

```
0012 652a           bcs.s   Error
0014 2d40           move.l  D0,Seed(A6)      Save the time as a random seed
          *
          * The following movem restores registers including the caller's
          * A6 register. It also clears the 4 bytes of nothing off the stack.
          * Popping the stack pointer only moves the stack pointer.
          * It doesn't actually load it from the stack. Including it in the
          * list of registers to be popped only causes the stack pointer to
          * move 4 more than it would have.
          *
0018 4cdf           movem.l (sp)+,D0–D3/A6–SP Restore registers
0000001c  Term      equ     *                Just return
001c 4e75           rts



          *
          * The main entry point for Silly is a dispatch routine that notes
          * the function code and calls the appropriate routine to service it.
          *
          * It is passed:
          *         D0–D7 and A0–A5: Caller's registers
          *         A6:     Trap handler's static data pointer
          *         SP:     Stack frame
          * The stack frame is:
          *         8(SP):  Caller's return address (4-byte)
          *         6(SP):  Vector number (2-byte)                   ignored
          *         4(SP):  Function code (2-byte)
          *         0(SP):  Caller's A6 register (4-byte)            ignored
          *
          * This trap handler deals with functions:
          *         1:      Return current time, formatted
          *         2:      Return given time, formatted
          *         3:      Return oracle's answer
          *         4:      Return a random number
          *
          *
          * Define stack offsets for convenience
          *
00000000            org     0
00000000  C.D0      do.l    1                Caller's D0
00000004  C.ORegs   do.l    6                Other registers
0000001c  C.A6      do.l    1                Caller's A6
00000020  FuncCode  do.w    1
00000022  Vector    do.w    1
00000024  RetAddr   do.l    1

001e 48e7 Entry     movem.l D0–D3/A0–A2,–(SP) Save registers
0022 322f           move.w  FuncCode(SP),D1 Get the function code
          * The function code must be 1, 2, 3, or 4.
```

```
0026 6f14              ble.s    FInvalid          Function le 0 is invalid
0028 b27c              cmp.w    #4,D1             Another range check
002c 6e0e              bgt.s    FInvalid          Function > 4 is invalid
          * Set function code up as an offset for a branch table
002e 927c              sub.w    #1,D1
0032 e541              asl.w    #2,D1             Multiply by 4 (length of bra)
0034 43fa              lea      BranchT(PC),A1
0038 4ef1              jmp      (A1,D1)

003c=7000 FInvalid     moveq    #E$IllFnc,D0      Illegal Function code error
003e=4e40 Error        os9      F$Exit            Quit

0042 6000 BranchT      bra      CTime             Format current time
0046 6000              bra      FTime             Format any time
004a 6000              bra      Oracle            Return oracle's words
004e 6000              bra      Random            Return random number

          *
          * CTime takes a pointer to a 25-byte buffer in A0.
          * It puts a formatted version of the current time with a suitable
          * comment in the buffer.
          *
0052 7000 CTime        moveq    #Gregorian,D0     Set the code for Gregorian time
0054=4e40              os9      F$Time            Get the current time
          * And drop through to FTime which will format it
          *
          * Format the time given in D0 into a buffer at A0
          *
          *
          * Describe the layout of the caller's buffer.
          * These offsets are used as offsets from A0 to define the
          * parts of the buffer that should receive various values.
          *
00000000               org      0
00000000  Hours        do.b     2
00000002  Colon1       do.b     1
00000003  Min          do.b     2
00000005  Colon2       do.b     1
00000006  Sec          do.b     2
00000008  Space1       do.b     1
00000009  AMPM         do.b     2
0000000b  Space2       do.b     2
0000000d  Comment      do.b     12

0058 1200 FTime        move.b   D0,D1             Move seconds from D0 to D1
005a 43e8              lea      Sec(A0),A1        A1→ place to put sec
005e 6176              bsr.s    bindec            Convert byte in D1 to decimal at A1
0060 e080              asr.l    #8,D0             Shift seconds out of D0
0062 1200              move.b   D0,D1             Move minutes from D0 to D1
```

```
0064 3400           move.w  D0,D2             Save hours/minutes for later
0066 43e8           lea     Min(A0),A1        A1→ place to put min
006a 616a           bsr.s   bindec
006c e080           asr.l   #8,D0             Shift minutes out of D0
006e 1200           move.b  D0,D1             Move hours from D0 to D1
          *
          * Fill in AM or PM according to whether it is before or after noon
          *
0070 117c           move.b  #'M',AMPM+1(A0) AM and PM both have M
0076 b23c           cmp.b   #12,D1            AM or PM?
007a 6c08           bge.s   PM
007c 117c           move.b  #'A',AMPM(A0)
0082 600a           bra.s   AMPMSet
0084 117c PM        move.b  #'P',AMPM(A0)
008a 923c           sub.b   #12,D1            Adjust to 12-hour clock
          AMPMSet
008e 43e8           lea     Hours(A0),A1
0092 6142           bsr.s   bindec
          *
          * Fill in constants
          *
0094 117c           move.b  #':',Colon1(A0)
009a 117c           move.b  #':',Colon2(A0)
00a0 117c           move.b  #32,Space1(A0)
00a6 117c           move.b  #32,Space2(A0)
          *
          * Find a suitable comment for the time.
          * Use the hours/minutes word that is saved in D2
          *
00ac 43fa           lea     CmtTabl(PC),A1 Address of Comment table
00b0 93fc           sub.l   #CTESize,A1       Back up to starting place
00b6 7008           moveq   #CTSize–1,D0

00b8 d3fc FCmtLoop add.l   #CTESize,A1       Point to next Comment
00be b451           cmp.w   (A1),D2           Check bound
00c0 5fc8           dble    D0,FCmtLoop

00c4 43e9           lea     2(A1),A1          Source for move
00c8 41e8           lea     Comment(A0),A0 Destination
00cc 700b           moveq   #12–1,D0          Size

00ce 10d9 MCmtLoop move.b (A1)+,(A0)+       Move comment to caller's buffer
00d0 51c8           dbf     D0,MCmtLoop
00d4 605a           bra.s   Return

          *
          * One-byte binary number is in D1
          * Convert it to a two digit decimal number at A1
          *
```

```
00d6 4881 bindec   ext.w    D1
00d8 48c1          ext.l    D1              Make the byte into a long
00da 83fc          divs     #10,D1          This gives us both digits
00de 1281          move.b   D1,(A1)
00e0 0619          addi.b   #$30,(A1)+      Decimal adjust
00e4 4841          swap     D1              Swap words
00e6 1281          move.b   D1,(A1)
00e8 0611          addi.b   #$30,(A1)       Decimal adjust
00ec 4e75          rts
00ee 6124 Oracle   bsr.s    NewRand         Get a random number
                   mod      D0,OTabSiz      MACRO
00f8 c0fc          mulu     #10,D0          Offset in table of 10-byte entries
00fc 43fa          lea      OTable(PC),A1   Point A1 at table
0100 d3c0          add.l    D0,A1           Bump A1 to the right entry
0102 7009          moveq    #10–1,D0        Number of bytes to move
0104 10d9 OLoop    move.b   (A1)+,(A0)+     Move wise words to caller's buffer
0106 51c8          dbf      D0,OLoop        Loop 10 times
010a 6024          bra.s    Return

010c 6106 Random   bsr.s    NewRand
010e 2140          move.l   D0,C.D0(A0)     Zap caller's D0 with rand #
0112 601c          bra.s    Return

0114 202e NewRand  move.l   Seed(A6),D0
0118 c0fc          mulu     #39709,D0
011c d0bc          add.l    #13,D0
                   mod      D0,65401
012a 2d40          move.l   D0,Seed(A6)
012e 4e75          rts

          *
          * Use the same trick as Init to clear an
          * extra long word off the stack.
          *
0130 4cdf Return   movem.l (sp)+,D0–D3/A0–A2/A6/SP
0134 4e75          rts

          *
          * Strings for time comments.
          * The layout is ending hour, ending minute, comment.
          *
0136 0400 CmtTabl  dc.b     4,0             Midnight to 4 AM
0138 5570          dc.b     "Up late! ",0
0000000e CTESize   equ      *–CmtTabl
0144 0800          dc.b     8,0             4:01 AM to 8:00 AM
0146 496e          dc.b     "In early ",0
0152 0b2d          dc.b     11,45           8:01 AM till 11:45 AM
0154 2020          dc.b     " ",0           Nothing to say
0160 0d00          dc.b     13,0            11:46 AM till 1 PM
```

```
0162 4c75              dc.b    "Lunchtime! ",0
016e 0f00              dc.b    15,0              1:01 PM till 3:00 PM
0170 2020              dc.b    " ",0             Nothing to say
017c 101e              dc.b    16,30             3:01 PM till 4:30 PM
017e 5465              dc.b    "Tea time?  ",0
018a 1200              dc.b    18,00             4:31 till 6:00
018c 5469              dc.b    "Time to go ",0
0198 1400              dc.b    20,00             6:01 PM till 8 PM
019a 476f              dc.b    "Go Home ",0
01a6 183b              dc.b    24,59             8:01 PM till midnight
01a8 2020              dc.b    " ",0             Nothing to say
00000009  CTSize       equ     (*–CmtTabl)/CTESize

01b4 5965 OTable       dc.b    "Yes "
01be 4e6f              dc.b    "No "
01c8 4d61              dc.b    "Maybe "
01d2 4465              dc.b    "Definitely"
01dc 476f              dc.b    "Go Away "
01e6 5768              dc.b    "Why Not?  "
00000006  OTabSiz      equ     (*–OTable)/10
000001f0               ends
```

The following program tests ***Silly***. It links to the ***Silly*** trap handler and calls each of its functions.

```
                       ttl     Exercise the Silly trap handler
00000001  Edition      equ     1
00000101  Typ_Lang     equ     (Prgrm«8)+Objct
00008000  Attr_Rev     equ     (ReEnt«8)+0
00000100  StackSiz     equ     256

0000000d  CR           equ     13                ASCII code for carriage return
00000001  StdOut       equ     1                 Standard Output path number
                       psect   Test,Typ_Lang,Attr_Rev,Edition,StackSiz,Entry
                       vsect
00000000  Buffer       ds.b    26
00000000               ends
          *
          * Collected strings and constants
          *
0000 5369 SillyName    dc.b    "Silly",0
00000001  T$Silly      equ     1
00000006               align
          *
          * Do TLink for Silly
          *
0006 7001 Entry        moveq   #T$Silly,D0       Chosen trap number for math
0008 7200              moveq   #0,D1             No extra static storage
```

```
000a 41fa          lea      SillyName(pc),A0 Point A0 at the name
000e=4e40          os9      F$TLink          Link to Silly as trap T$Silly
0012 6540          bcs.s    Exit
            *
            * Use the "Silly" functions
            *
0014 41ee          lea      Buffer(A6),A0
0018 4e41          tcall    T$Silly,1        Get formatted current time
001c 1d7c          move.b   #CR,Buffer+25(A6) Seal with a CR
0022 7001          moveq    #StdOut,D0
0024 721a          moveq    #26,D1
0026=4e40          os9      I$WritLn
002a 203c          move.l   #$000D1620,D0 A time, 1:22:32 PM
0030 4e41          tcall    T$Silly,2        Format a given time
0034 1d7c          move.b   #CR,Buffer+25(A6) Seal with a CR
003a 7001          moveq    #StdOut,D0
003c 721a          moveq    #26,D1
003e=4e40          os9      I$WritLn
0042 4e41          tcall    T$Silly,3        Get words of oracle
0046 7001          moveq    #StdOut,D0
0048 720a          moveq    #10,D1
004a=4e40          os9      I$WritLn
004e 4e41          tcall    T$Silly,4        Just get a random number
0052 7200          moveq    #0,D1            Clean return
0054=4e40 Exit     os9      F$Exit
00000058           ends
```

Chapter 15

OS-9 I/O

Unless you write operating-system-level code, you'll never deal with input/output (I/O) hardware. The I/O manager-file manager-device driver hierarchy isolates you from the hardware by presenting you with an abstract view of files. High-level languages may pile on yet another layer of abstraction. Other chapters consider I/O from various points within OS-9. This chapter views files from a program's viewpoint.

15.1 The Unified File System

Different devices have different characteristics, but OS-9 protects user programs from device peculiarities as much as it can. This doesn't mean that OS-9 ignores the special qualities of each device class. Random access is an important feature of RBF files. OS-9 doesn't hide the random access capability of disks in order to make disk files compatible with SCF files. What a unified file system does mean is that a reasonable number of I/O operations work predictably across all the file types and devices. These operations are: I$Create, I$Open, I$Close, I$Read, I$ReadLn, I$Write, and I$Writeln.

All the OS-9 utilities and most other programs limit their operations on the three standard paths to this group of SVC's (actually, they leave out I$Open and I$Close because the standard paths are open when a program starts). Because of this policy and the uniformity of the OS-9 file systems, you can redirect the input and output of programs without considering the types of the files. It is entirely normal for a person to redirect the output of a program from his terminal to a printer, a pipe, or a disk file.

15.2 Paths

A program sees files as paths. OS-9 keeps a path descriptor for each path and gives programs numbers that identify them. When a program reads from standard input, it is reading from path 0. When it writes a message to the standard error path, it is writing to path 2. When it opens a file, I$Open returns a new path number (say, 3) for the program to use for subsequent operations on that file.

Each process can have up to 32 paths open at any time. All the OS-9 I/O services use a path number to find a path descriptor which defines the environment for the operation. The path number leads to a system path number which in turn leads to a path descriptor. The path descriptor holds everything that distinguishes the path.

From a program's point of view, a path number is a name for an open file, but it is also a name for a path descriptor. A program can get several paths (and several path descriptors) to a file by opening the file several times. Each path has a distinct path number and path descriptor. A program can also get several paths that lead to the same file *and have the same path descriptor.*

The I$Dup system call is passed a path number. It returns a new path number that shares the same path descriptor. Since duped paths share a common path descriptor, they share the path options. If you want to open several paths to one device with the same options, the I$Dup SVC is the easiest way to do it.

15.3 Path Options

You can see the effect of duped paths when you use the tmode command. Changes you make to one of the standard paths almost always affect all three. This is because ***sysgo*** and ***tsmon*** start the shell with a path to the terminal duped into all three standard paths.

If you want to open a path with fresh options, just open it. The I/O system builds you a fresh path descriptor from the device descriptor. Things can get tricky here. A device is initialized whenever the number of paths using the device goes from zero to one. The second path to the device doesn't cause it to be reinitialized. This caused a problem since programs could not adjust device behavior such as baud rate, XOn/XOff, and disk stepping rate. Now, well-behaved device drivers respond to SS_Opt setstat calls by updating popular parameters as requested. SCF drivers usually do a good job with options. RBF drivers are not so uniformly good with options. The main RBF hardware option a program might change with a setstat is disk stepping rate, and the drivers that specify the stepping rate for each command generally respect the value in options while those drivers that set the stepping rate when a driver is initialized sometimes fail to notice the change.

You can also change device initialization parameters by altering the device descriptor, but only if you subsequently initialize the device.

15.4 Device Attributes

Devices all have attributes. They are stored in the device descriptor and used whenever a path to the device is opened. The attributes determine what operations are valid on the device. A printer, for example, is writable, but reading or executing from the printer would probably be forbidden. Printers are also usually not sharable. A shared printer might mix printouts together. It is better to be told that the printer is busy than to have your listing combined with someone else's.

15.5 Reading and Writing

The I$Read and I$Write SVC's underlie all unformatted I/O. They move data directly between your program and the file. There is, however, an exception: if you have software handshaking active on an SCF path, the protocol is treated as a property of the device. The flow-control characters are not included with data that is read.

When you do I/O to SCF devices you may want to use the extra power of the I$ReadLn and I$WritLn SVC's. These calls use the parameters in the path descriptor's option section to do line editing.

For the I$WriteLn SVC, line editing amounts to adjusting the output to fit the peculiarities of the output device.[1]

OS-9 terminates each line with a carriage return, but some SCF devices need a line feed after the return. There is an "auto linefeed" option to allow SCF to adjust to this. Some devices (especially old mechanical devices) need to be fed a stream of nulls while they do time-consuming operations. The "end of line null count" option tells SCF to send the specified number of nulls to cover each return. These days very few devices can't handle lower case letters, but if you use one of the few, there is an option that makes all letters upper case.

The pause option is for human consumption. If you list a file to a terminal with the pause option off, it will fly by at whatever rate the terminal can handle. There are two options that can help. One option, "end of page pause," causes output to stop after each page is displayed and instructs SCF to wait for a character (any character) to

[1] It used to be possible to trick SCF into writing several lines with one I$WriteLn SVC. The operation only writes characters up to the first carriage return. The trick was that it processed carriage returns or line feeds as new lines, but only a carriage return would end the writeln. If you wanted to write several lines with one I$WriteLn, separating them with line feeds would cause the output to look like the output from a set of I$WriteLn's. This "bug" is now fixed, and it is time to fix old programs.

be typed before proceeding. The other option, "pause character," names a character that you can type to pause output.

The "end-of-page pause" option uses the "page-length" option. In addition to being used by SCF for page pausing, the page length stored in the path descriptor and device descriptor is a convenient place for user programs to discover the number of lines on a page for a device.

The `I$ReadLn` SVC does input line editing. Many of the path options affect the amount or type of line editing it does. By including the line editing function in SCF, OS-9 makes it possible for individual programs to ignore the problem. It also makes a standard interface available.

To a program, the most important part of line editing is that it handles backspaces (though backspace processing is not the only form of input editing delivered by SCF). Unless backspace processing is disabled, the buffer returned from an `I$ReadLn` looks just the way the line looked on the screen. Backspaces, and the characters before them, are eliminated by SCF.

The `I$ReadLn` and `I$WritLn` operations may not be as fast as the simpler `I$Read` and `I$Write` SVC's. They shouldn't be used unless their line-editing capability is required.

The most efficient way to read or write is to use big blocks. A large part of the cost of each I/O operation is constant overhead. You spend the overhead for each SVC, so stretch it as far as you can by transferring lots of data.

15.6 The Keyboard Signals

Two signals can be sent to a process with single keystrokes: the keyboard interrupt and the keyboard abort. These signals are sent to the process that last used the device—not to the last process to gain access to the device. This distinction is important. A process is not vulnerable to the keyboard signals until it "uses" the keyboard device. Reading or writing constitutes using a device—inheriting a path to it or checking its status does not.

If you fork a process and wait for it to complete, you should be ready for a keyboard signal. Even though the child process has dups of your paths, the devices for the paths send any signals to you until your child is recognized as the last user of the device. It is an interesting question what you should do with a signal that wasn't meant for you.

The shell demonstrates misdirected signal handling nicely. The signal releases it from a wait. If the signal was a keyboard kill (signal 2), the shell forwards the signal to its child and prints `abort`. If the signal was a keyboard interrupt (signal 3), the shell continues as if the forked process had finished. The reaction to the signal is simple (though not immediately obvious) and useful. You can use this trick to push a process into the background after you start it. Start a process that doesn't use the terminal:

```
$ cc HugeProgram.c »>Prog.Out
```

then realize, too late, that you should have used an ampersand on the command line. You can bail yourself out with a control-C. Type control-C and the shell will respond with `interrupt` and give you a new prompt. The compile continues undisturbed.

15.7 Signal on Data Ready

Reading data from a path is simple: you do the read, and it returns to you when it has collected the data. So what do you do if you can't wait for the data to arrive? If you are expecting data on any of several paths, you can't let yourself get stuck in a read for one of them. Every telecommunication program is plagued by this problem. It needs to wait for input from the keyboard and the modem, and can't let itself get stuck waiting for either of them.

One solution is to poll the paths. Put your program in a loop where it does `I$GetStt` SVC's testing for data ready on each path of interest. When some data appears, read it. This works, but it uses large amounts of CPU time doing almost nothing. It doesn't respond to input very fast either.

The cleanest way to handle this problem is to use the "send signal on data ready" `I$SetStt` option on each SCF path you want to read. This instructs OS-9 to send you a signal when data is ready on any of the paths. Even better, you can ask it to send you a different signal for each path (provided the paths are to separate devices). You set up an intercept routine with the `F$Icpt` SVC, and plant one of these signal trip wires on each path from which you expect data. Then you sleep. When there is data to read, a signal wakes the process and tells it where to look for data.

This system is not perfect. A few timing problems can catch you if you aren't careful.

- The wakeup signal can be lost if it arrives when the process is not sleeping.
- Even if multiple signals are queued, the process is only awakened once. The intercept routine is called once for each queued signal, then the sleep ends. A program that does not account for this possibility can fail to notice that several paths may have data when it is awakened.

If input is already buffered when the process starts, the request for a signal on data ready will send a signal immediately. It is serviced by the intercept routine, and leaves a wakeup in the process descriptor that will cause the next sleep to return immediately.

Waiting for signals from paths has a subtle useful feature when compared to simply waiting in `I$Read`. Although a device with a "set signal" pending is considered too busy for any path to read, writes to the device can proceed while you wait for input.

Figure 15.1: Signal on Data Ready Protocol

```
    Empty IntQueue
    Set up an signal trap that enqueues the signal number on IntQueue.
    Set a trip wire for signal x on path x.
    Set a trip wire for signal y on path y
Loop:
    Sleep
    for each path in IntQueue
        Dequeue the path number.
        Use an I$GetStt for data ready to determine how much data is ready.
        Read all the data that's ready from the path.
        Set a new trip wire on the path.
    goto Loop
```

15.8 Modem Control Commands

Some SCF drivers are able to send signals when they detect or lose data carrier. This can be used to initiate special processing when a modem connects or disconnects. The SS_DCOn and SS_DCOff `I$SetStt` calls assign signal number to transitions of the DCD line.

Other setstats control the request to send (RTS) handshake line. SS_EnRTS enables RTS and SS_DsRTS disables the line. Some modems come off hook when they detect RTS and hang up when RTS drops.

15.9 Adjusting RBF File Size

OS-9 uses a simple rule to determine the length of a file. Every point in the file that you write to or even point to with an `I$Seek` while the file is open for writing is in the file. You can increase the size of a file by seeking to the new end of the file.

Shortening a file is another problem. OS-9 won't shorten a file unless it is explicitly asked. The `I$SetStt` set-filesize option can be used to shorten or lengthen a file.

As you write to a file or seek beyond its end, OS-9 allocates disk space to you in chunks that may be more than a sector long. The idea is that the bigger the chunks it gives to you, the less fragmented a large file will be. Normally, the unused space is returned to the system when you close the file, but if you don't leave the current location pointing at the end of the file when you close it, OS-9 will leave the unused space attached to the file. If you expect to expand a file later, you can help prevent it from being fragmented by rewinding the file before you close it. You must do this every time you close the file after opening it for writing or updating. The first time you close a writable file with the current location pointer at the end of the file, OS-9 reclaims the unused space.

15.10 Record Locking

If you only run one process at a time, you will never have to worry about contention for disk files, but you would be a most unusual member of the OS-9 community. Since OS-9 is a multitasking operating system, it includes tools to help you manage shared files. If you have an RBF file open for update, OS-9 gives you ownership of the last block of data you read. Until you read or write that file again no other process can touch the data you have claimed. This prevents lots of nasty timing-dependent problems.

The best way to see what record locking does is to watch what can happen without it. Lets say we have two processes, one and two, both updating file A.

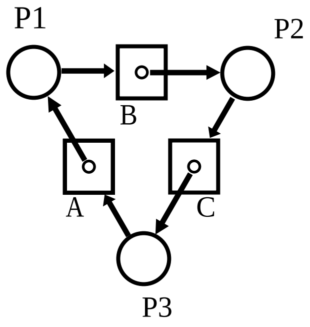
- Process one reads the first 100 bytes of A.
- Process two reads the first 100 bytes of A.
- Process one updates what it read with lots of important data and writes it back to A.
- Process two makes a trivial change to what it read and writes it back to A.

The changes made by process one are overwritten by process two. Process one might as well have never existed. For a full appreciation of the trouble this can cause, imagine that the two programs pace one another through the file, alternating the order in which they write their updates. Both programs believe that they successfully updated the file, but the actual result is a mess with half of the records reflecting process one's changes and the other half updated by process two.

With record locking in place, process one would have locked the first 100 bytes of the file when it read them. When process two went to read the same data, it would be locked out. It would wait for process one to read or write before it continued. The result is that process one updates the record, then process two updates it.

In one case, a path that is only open for writing (not updating) can lock a record. Reading or writing data at the end of a file asserts an end-of-file lock. This lock keeps things straight if several processes want to extend a file. It also lets a process follow along behind another process that is extending a file. If you redirect the standard output of a program to a disk file, then list the file to a printer. You will see the end-of-file lock

Figure 15.2: Example of Three-Way Deadlock



in action. The ***list*** program won't read what is written to the file and reach the end before the program writing the file has finished. The end-of-file lock that the writer keeps on the file keeps ***list*** from reaching the end of the file until the writer is done.

Record locking for RBF files prevents many problems, but it creates some new ones. Holding a lock you don't need is not good behavior. Imagine how frustrating it would be if someone read and locked a record, then went out for lunch. That record might not be available to anyone else for hours! A program that doesn't plan to update a record that it reads can release the record by using the `I$SetStt`/SS_Lock SVC for a length of zero.

Deadlock and lockout[2] are other problems that only occur when resources can be locked. You'd have to struggle to get OS-9 to let you into a lockout situation, so we'll ignore that problem except to define it. You have lockout when a process can get to a resource (e.g., part of a file), but other processes conspire to keep it out. Lockout is mostly a problem for theorists to worry about. Deadlock is easier to get and more serious than lockout.

Deadlock takes place when two or more processes each are holding resources that the other processes require. Let's say you and a friend are ready to make an ice cream cone. You grab the cones and go for the ice cream. He grabs the ice cream and goes for the cones. You both stand there waiting for the other to put down what he has. If your algorithms don't allow for this kind of problem you are both stuck—deadlock.

The same problem can happen with record locks. To make the example more interesting, let's use three processes: one, two, and three. Each process wants to execute the following steps:

- Read a byte from one file
- Read a byte from another file

[2] Deadlock is sometimes called Deadly Embrace and Lockout is also known as Starvation.

- Update the first file
- Update the second file

If the three processes are not arranged correctly, we can get into trouble.

- Process one reads the first byte of file A
- Process two reads the first byte of file B
- Process three reads the first byte of file C
- Process one tries to read the first byte of B and sleeps for a record lock
- Process two tries to read the first byte of C and sleeps for a record lock
- Process three tries to read the first byte of A and sleeps for a record lock

We have a three-way deadlock. Those three process sit there locking up the three files until they are killed.

The first rule for avoiding deadlock is that all processes locking more than one resource should request resources in the same order, say alphabetically. In the example, process three read the files in reverse alphabetical order. If it read them in order it would have tried to read file A before file C. It wouldn't have locked A until process one was done, so it wouldn't have locked C. Since C wasn't locked, process two could read it and update B and C. When process two updated B, it would release process one. Eventually all the processes would complete. By having all the processes lock the files in the same order we avoided deadlock.

Remember that files aren't the only resources that can be locked. Any non-sharable resource is locked when you have access to it; i.e., files with the non-sharable attribute and devices that are not sharable. When you open a path to a non-sharable printer, you lock that device.

If you can't count on all processes to follow a simple rule, like requesting resources in alphabetical order, you may have to write programs that deal with deadlock. If OS-9 detects a deadlock, it returns an error from the operation that caused it to detect the deadlock. That process can try to deal with it. It could just retry the operation, or it could free everything it has a lock on, sleep for a short time and start locking again. Either trick might work.

If you don't trust OS-9's deadlock detection algorithm, or if you don't want to wait for a long time for some part of a file even if it isn't held by a deadlock, you can use `I$SetStt`/Ticks. to specify the number of ticks that you will wait for a locked-out operation to complete. If that interval expires, the operation returns to you with an error, E$Lock.

Chapter 16

The I/O Manager

OS-9 includes a separate module called IOMan. This module contains the operating system code responsible for managing I/O paths. This chapter covers the philosophical role of IOMan and many of its practical duties.

The Input/Output Manager, IOMan, does just the things you would think a manager should do. IOMan catches each call for I/O services, collects the necessary resources, and passes the request to the appropriate file manager.

IOMan sits at the top of the I/O hierarchy. It processes every I/O system service request. For open and create requests, it creates and initializes a path descriptor and forwards the request to the proper file manager. For SVC's that pass a path number, IOMan finds the corresponding path descriptor and passes it to the file manager. Some requests, such as make directory and delete file, don't explicitly use a path descriptor. For these SVC's IOMan creates and initializes a path descriptor, then destroys it when the file manager returns to it. IOMan takes responsibility for the security of read and write requests. It uses the `F$ChkMem` SVC to check the pointer and length values that the process passes as arguments to I/O SVCs. If SSM is installed, it uses MMU hardware to check the process's right to access the memory. If SSM is not installed, `F$ChkMem` only ensures that the memory is accessible to the kernel.

16.1 Attach/Detach

The attach request is unusual. It is seldom used except by the I/O Manager itself. It places a new device in the device table and calls the device driver to initialize it. The device table is a quick reference table used by the I/O Manager to determine whether a device is already attached. Knowing whether a device is attached prevents IOMan from wasting time attaching it again. It also prevents IOMan from having the driver reinitialize the device. All the facts that Attach collects about a new device are contained in the device table; these facts can then be taken from the table each subsequent time the device is opened.

Detach is the inverse operation for Attach. It decrements a device's use count. If the use count becomes zero, IOMan removes the device from the device table and calls the termination routine for the device.

Users seldom attach a device; however, they often open files. When a file is opened, IOMan attaches the device if necessary. It also creates a path descriptor for the new path, and calls the file manager to do anything it might need to do about a new file; e.g., find the location of an RBF file on disk.

16.2 Duping Paths

Use a `I$dup` SVC when a path number needs to be changed. IOMan is responsible for Dup. It assigns an additional path number to a path descriptor and increments the use count of the path descriptor. This sounds like a trivial operation, but it is the only way to save the path descriptor for a path if you have to close it.

A program might need to open a path to the printer as standard output without losing the current standard output file. This can be done by:

```
dup path 1 standard output
save the new path number x
close path 1

open the printer
```

The printer appears as path 1 because IOMan always assigns the lowest available path number and path 0 is already taken by standard input.

To restore the original standard output file:

```
close path 1
dup path x
```

Path *x* is the dup of the original standard output. It is duped to the lowest available path number. Since we just closed path 1, releasing that path number, this dup is to path 1.

```
close path x
...
```

Close is another operation on which IOMan may act. If the use count of the path descriptor for the path being closed is greater than one, the I/O Manager just decreases it by one. If the use count is one, there aren't any other paths using the descriptor so

IOMan returns the memory for the descriptor. If there are no other paths using the device, IOMan also detachs the device.

The real working I/O operations are passed right through the I/O Manager to the file manager. IOMan passes read and write requests through to a file manager as fast as possible, and wouldn't know a directory or a carriage return if it bit "him" on the nose. Its only involvement with the bulk of commands is to get the address of the path descriptor and pass it along to a file manager.

The I/O Manager takes requests for services, arranges the paper work, and gets the right team of modules together. Its main direct involvement is at the start and end of a project (Open and Close). The noun, "manager," fits IOMan exceptionally well.

Chapter 17

Pipes

This chapter covers pipes. You will learn how to create named and unnamed pipes, and some of the things for which they can be used.

Pipes are sequential files that never leave your system's RAM memory. They can be made large if you are willing to dedicate a lot of memory to them, but usually a pipe uses only a small amount of RAM. It is possible to store bulk data in a pipe, but in most cases, data only stays in the pipe briefly as it passes between two processes. Even a one-byte buffer would suffice.

17.1 Unnamed Pipes

Unnamed pipes are only known by their path numbers to the process that created them. Like any path they can be inherited by a process' children. That's what makes unnamed pipes useful. First let's consider creating a pipe that is only known to the process that created it.

If you write enough data into a pipe to fill its buffer, the write blocks until enough data is emptied from the pipe to allow the write to complete. If only one process has access to a pipe, a blocked write is trouble. Since the only process that can read from the pipe is the writer—the one that is blocked—the process waits here until it is killed.

A fork with both ends at one process is not a completely absurd idea. If you are careful never to write enough data to the pipe to fill it, a pipe that is known to only one process has some limited use as a storage place for a queue. It can be used to implement strong separation between objects in a single process.

If you fork a process while you have a pipe open, you can pass the pipe's path number to the new process. Now two processes have access to the pipe and it can be used as a communication device between those processes. In the following example, a process starts a child that feeds it the square roots of the integers one through ten.

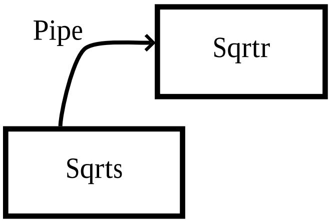
Piping the standard output path of a child process back to its parent is a good trick. The most common use is to get the output from a system utility command.

```
#include <stdio.h>
#include <process.h>
#include <const.h>
#include <errno.h>
#include <types.h>
#include <modes.h>
/*
    This program starts Sqrts, a program that generates the square roots of
    the numbers one through ten. It fixes it so the standard output of Sqrts
    is a pipe that leads to a path here. We don't do anything reasonable
    with the numbers, just add them up and print out the total.
*/

extern char **_environ;
char *Sqrts_ArgList[] = {
    "Sqrts",
    NULL
};



main()
{
    path_id SaveStdout;
    path_id PipePath;
    path_id One;
    process_id sqrts_process;
    u_int32 ct;
    double x, Total;

    /*
        Dup the stdout path so we can mess with it.
    */
    if((errno = _os_dup(1, &SaveStdout)) != SUCCESS){
        perror("duping stdout");
        exit(errno);
    }
    /*
        Now close stdout to make room for the pipe. Don't bother to tell stdio
        about this. We'll put it back before he notices.
    */
    (void)_os_close(1);
    /*
        Open a pipe. It will go into path one because that is the lowest-
        numbered free path
    */
    if((errno = _os_open("/PIPE", FAM_READ+FAM_WRITE, &One)) != SUCCESS){
        perror("opening /PIPE");
        exit(errno);
    }
    /*
        The pipe is all set. Let's start sqrts.
    */
    if((errno = _os_exec(_os_fork, 0, 3, "Sqrts", NULL,
    _environ, 0, &sqrts_process, 0, 0)) != SUCCESS){
        perror("failure forking Sqrts");
        exit(errno);
    }
    /*
        We need stdout back, but don't want to lose the pipe file. So dup the
        pipe, close the original pipe and put the original stdout back where it
        belongs.
    */
    (void)_os_dup(1, &PipePath);
    (void)_os_close(1);            /*close original pipe */
    (void)_os_dup(SaveStdout, &One);          /*Will go into path 1 */
    (void)_os_close(SaveStdout);          /*We're through with this */
    /*
        We're ready to roll. The paths are now:
        0 Standard input
        1 Standard output
        2 Standard error
        3 The dup of stdin.
        4 The pipe path.
        For Sqrts, path 1 is the other end of the pipe.
    */
    Total = 0;
    ct = sizeof x;
    while((errno = _os_read(PipePath, &x, &ct)) == SUCCESS)
    Total += x;
    printf("Total of Square roots is %lg\n", Total);
    exit(0);
}
```

The next program is the one forked by the previous program. There is no clue in the program (except the comments) that it will write to a pipe.

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

Figure 17.1: A Pipe Between Child and Parent



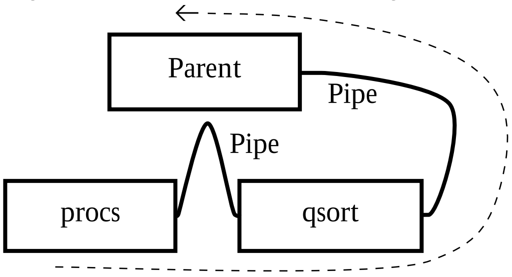
```
#include <math.h>
#include <types.h>
/*
   This program simply writes square roots of the first ten integers to its
   standard output path. The output will be real numbers. We have a
   choice of two ways to write the data. We can format the output for
   human consumption and terminate each number with a return, or
   we can write them in internal form (as doubles). Just to show that
   pipes can handle non-printable data, we'll send the data in its internal
   representation.
*/
main()
{
   u_int32 Counter;
   double Square_Root;

   for(Counter=1;Counter<=10;++Counter){
      Square_Root = sqrt((double)Counter);
      fwrite(&Square_Root,
      sizeof Square_Root,
      1,
      stdout);
   }
   exit(0);
}
```

17.2 Shell-Style Pipes

The shell uses pipes to let you hook processes together stdout-to-stdin. It takes a little playing with path numbers, but you can do the same trick yourself. The following example pipes the output of ***procs*** to ***qsort***, and reads the output of ***qsort*** from another pipe.

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

Figure 17.2: Pipes Between Sibling Processes



```
#include <modes.h>
#include <errno.h>
#include <const.h>

#define BUFFERSIZE 133

/*
    This program demonstrates pipes between sibling processes. Since the
    previous example covered basic pipes carefully, this one will hurry
    through most of the duping and concentrate on the sibling bit.
*/

extern int _os_fork();
extern char **_environ;

char *Procs_Arglist[] = {
    "procs",
    0
};

char *Qsort_Arglist[] = {
    "qsort",
    "-f=2",
    0
};

main()
{
    path_id SaveStdin, SaveStdout;
    path_id PipePath, Zero, One;
    process_id procs_process;
    process_id qsort_process;
    char buffer[BUFFERSIZE];
```

```
u_int32 ct;

/*
    Build a pipe for stdout
*/
if((errno = _os_dup(1, &SaveStdout)) != SUCCESS){
    perror("duping stdout");
    exit(errno);
}
(void)_os_close(1);
if((errno = _os_open("/PIPE", FAM_READ+FAM_WRITE, &PipePath)) != SUCCESS){
    perror("opening /pipe");
    exit(errno);
}

/*
    Start procs with its output going to a pipe
*/
if((errno = _os_exec(_os_fork, 0, 3, Procs_Arglist[0], Procs_Arglist,
        _environ, 0, &procs_process, 0, 0)) != SUCCESS){
    perror("failure forking procs");
    exit(errno);
}
/*
    Move the pipe to stdin
*/
(void)_os_dup(0, &SaveStdin);
(void)_os_close(0);
(void)_os_dup(1, &Zero);                    /*Dup the pipe (in stdout) to path 0 */
/*
    Open a NEW pipe for stdout
*/
(void)_os_close(1);
(void)_os_open("/PIPE", FAM_READ+FAM_WRITE, &One);
/*
    Now start qsort with both stdin and stdout going to pipes.
*/
if((errno = _os_exec(_os_fork, 0, 3, Qsort_Arglist[0], Qsort_Arglist,
        _environ, 0, &qsort_process, 0, 0)) != SUCCESS){
    perror("failure forking qsort");
    exit(errno);
}
```

```
    /*
        We don't need the pipe between procs and qsort any more. They can
        take care of it. Close that pipe and move the other to a special path so
        we can read from it and use the original stdout.
    */
    (void)_os_close(0); /*close one of the pipes */
    /*
        We don't plan to use stdin again, but lets put it back where it belongs
        just to keep everything neat.
    */
    (void)_os_dup(SaveStdin, &Zero);
    (void)_os_close(SaveStdin);

    (void)_os_dup(1, &PipePath);
    (void)_os_close(1);
    (void)_os_dup(SaveStdout, &One);
    (void)_os_close(SaveStdout);
    /*
        Now we're all set. The paths open now are:
        0 The original stdin
        1 The original stdout
        2 The original stderr
        4 A pipe leading to qsort's stdout
        We could use fdopen to turn the pipe path into a full C file, but for the
        simple reading we mean to do, a plain path will do.
    */
    printf("(Process ID, Parent ID) sorted by parent ID\n");
    ct = BUFFERSIZE;
    while((errno = _os_readln(PipePath, buffer, &ct)) == SUCCESS){
        /*pick the first 7 chars of line */
        buffer[7] = '\0';
        /*If it isn't the header line print it */
        if(buffer[1] != 'I')
        printf("(%s) ", buffer);
        ct = BUFFERSIZE;
    }
    printf("\n");
    exit(0);
}
```

Pipes are almost always used with one process at each end, but that is not a restriction. If you have several readers and several writers on a pipe, the pipe file manager will do the best it can for you. It ensures that data which is written in one write arrives in one piece, provided that the process that reads it issues a read for the right amount of data.

Once a process does a read or write to a pipe, it has control of that end of the pipe until the operation completes. If the pipe can't hold the entire amount you want to write, it blocks the write until some data is read from the pipe. When it is empty enough to permit more writing, it lets the blocked process continue. In the same way, if a pipe doesn't hold enough data to satisfy a read, it gives the reader all it can, then blocks until more data is written to it. Other processes waiting to read or write wait until the current processes have finished.

In general, OS-9 tries to prevent a resource from being monopolized by any process. However, if pipeman didn't use the locking algorithm it does, any message longer than one byte could be scrambled by other messages. A process might write, say, ten bytes of a five-hundred byte message into the pipe. Another process might then get the pipe and write fifty bytes into it. The first process might get back in and finish its write. Meanwhile, one process could read the first fifty bytes and another process empty the pipe. Both readers would receive garbled messages.

Sending and receiving fixed-length messages on a shared pipe isn't too hard. If the messages must be variable length, you must use readln and writeln. Tricks like coding the length of the message into its first two bytes would only work if you could read the first two bytes of a message, then read the rest. Given the way pipes are shared, you couldn't count on the rest of the message being there when you went back to read it.

17.3 Named Pipes

Unnamed pipes can be passed among closely related processes, but they can't get out of the immediate family. Named pipes are accessible to any process that knows the pipe's name. I$Create is all that is required to create a named pipe, which will exist as long as any paths lead to it or there is any data in the pipe. A pipe name is the name of a pipe device (/PIPE is the default descriptor) followed by up to 28 characters that follow the usual OS-9 file naming conventions.

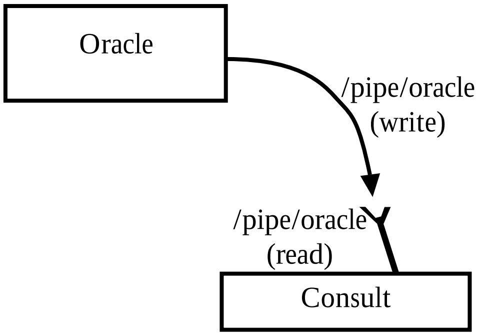
Examples that use Pipe Names

```
$ copy test.file /pipe/test.pipe
$ list /pipe/test.pipe

PipeFile = fopen("/pipe/x", "w");
```

Choose a pipe's name carefully. It must be unique, and, somehow, the programs that want to use the pipe have to know its name. Still, a pipe with a well-known name can be used by any process in the system. It's an elegant way to get at a shared resource.

You can begin to get a feel for named pipes without writing any code. Try listing a file into a named pipe:

Figure 17.3: Named Pipes



```
$ list /dd/defs/oskdefs.d >/pipe/test&
```

You'll see the program start up, then nothing happens. It filled the pipe and is waiting for someone to read from it. You can see the named pipe with the ***dir*** command. Try:

```
$ dir /pipe
```

You'll see `test` in the directory listing.

You can read from the pipe as if were a normal file:

```
$ list /pipe/test
```

and you'll see the contents of /dd/defs/oskdefs.d.

There are some differences between named and un-named pipes. (There's the name, of course.) A named pipe is meant to be opened from one end, then wait for someone to open the other end. You can write to a named pipe with no readers; try that on an un-named pipe and you'll get an error. You can also leave a named pipe around with no processes attached to it provided you leave some data in it.

Named pipes are best used with servers. Here's a program that I call an ***oracle***. It pumps answers into a pipe. Any other process can get an answer from the ***oracle*** by reading the pipe.

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

#define PIPENAME          "/PIPE/Oracle"
#define FOREVER           1

#define ANSWERCT          8
```

```
char *Answer[ANSWERCT]={
    "Yes",
    "No",
    "Of course",
    "Absolutely not",
    "Why not",
    "Huh?",
    "Maybe",
    "The Oracle is sleeping"
};


/*
    Prototypes
*/
u_int32 Rand(void);

main()
{
    FILE *Pipe;

    /*
        Open the named pipe just like any file
    */
    if((Pipe = fopen(PIPENAME, "w")) == NULL){
        fprintf(stderr, "Can't open %s.  Error %d\n", PIPENAME, errno);
        exit(errno);
    }
    /*
        Execute the next statement until the world ends.
    */
    while(FOREVER)
    fprintf(Pipe, "%s\n", Answer[Rand()]);
}


static long seed=0;

u_int32 Rand() /*return a random number */
{
    int time, date, tick;
    short day;

    if(seed == 0){
        _os_getime(3, &time, &date, &day, &tick);
        seed = date + (tick & 0xffff);
    }
    seed = abs((seed * 39709L + 13L) % 65537L);
    return (seed % ANSWERCT);
}
```

The next program, called ***consult***, consults the oracle. It opens the pipe for reading and reads one line from it. It uses raw OS-9 I/O because it needs to be sure of using a readln in order to get just one line from the pipe.

```
#include <stdio.h>
#include <modes.h>
#include <types.h>
#include <errno.h>
#include <const.h>

#define ANSWERLENGTH            100
#define ORACLENAME              "/pipe/oracle"

main()
{
    char Answer[ANSWERLENGTH];
    path_id PipePath;
    u_int32 ReadLength;

    /*
        Don't open a full C file. We don't want the pipe buffered. (We only
        want to read one line from it.)
    */
    if((errno = _os_open(ORACLENAME, FAM_READ+FAM_WRITE, &PipePath)) != SUCCESS){
        fprintf(stderr, "The oracle doesn't answer\n");
        exit(errno);
    }

    ReadLength = ANSWERLENGTH;
    if((errno = _os_readln(PipePath, Answer, &ReadLength)) != SUCCESS){
        fprintf(stderr, "The oracle curses\n");
        exit(errno);
    }

    /*
        The string from Readln isn't terminated with a 0 byte. Stick one on
        the end.
    */
    Answer[ReadLength] = '\0';
    printf("%s\n", Answer);
    exit(0);
}
```

To use the oracle, you first start it running in the background:

```
$ oracle&
```

The oracle should just keep running. It only uses time when it has to refill the pipe. To consult the oracle, run ***consult***:

```
$ consult
```

Consult reads a line from the oracle's pipe and prints it on your terminal.

Chapter 18

Interrupts

In this chapter you will learn what interrupts are and how they relate to I/O and multitasking.

Interrupts are requests for the processor chip's attention. When a 68000-family processor accepts an interrupt, it stops what it is doing, enters system state, and executes some code to "service" the interrupt. In a sense, an interrupt is a switch that the hardware outside the microprocessor can use to cause the microprocessor to execute special subroutine calls. Interrupts are usually serviced as soon as they are raised (caused), but the processor can ignore interrupts by masking them.

The 68000 family of microprocessors can deal with external interrupts at seven priority levels. The first thing the processor does when it services an interrupt is to mask all interrupts except those at higher priorities than the interrupt it is servicing. The interrupt mask can be adjusted by altering the system byte in the status register.

The processor can also generate numerous internal interrupts, called exceptions. Some exceptions are friendly, like the `trap` interrupts which call trap handlers and OS-9 SVCs. Other exceptions indicate unfortunate occurrences like addressing nonexistent memory or trying to divide by zero.

All interrupts (including software exceptions) do about the same things. They push the processor's context on the system stack, find a "vector," and jump to that address. Each type of interrupt gets the address it jumps to from a different place. This makes it easy to handle each type of interrupt with a different routine.

Most interrupts get their vectors directly from a vector table. The VBR register points to the vector table on the more advanced members of the 68000 family. On early processors—the 68000, 68008, and 68070—the vector table is fixed at addresses 0 through 1024. The division-by-zero exception, for example, causes a branch to the address at offset 20 ($14) in the vector table.

Hardware interrupts can select any vector from the vector table by vector number, or they can use the default vector assigned to each interrupt level. Interrupts that specify a vector number are called vectored interrupts, and interrupts that only provide an interrupt level are called autovectored interrupts. A pin on the chip indicates to the processor whether an interrupt is vectored or autovectored.

Interrupt level seven cannot be masked by software. Since software cannot protect itself against interruption by level seven interrupts, that level must be used carefully. The safest rule is to avoid level seven interrupts entirely, but they are tempting. The only latency for level seven interrupts is whatever delay is built into the hardware. Sometimes level seven interrupts may be the best way to guarantee very fast and repeatable interrupt response time. But since they can interrupt the kernel at any time, *don't make system calls or touch system data structures from level seven interrupt service routines.* Treat any data structures shared between level seven interrupt service routines and other code with extreme care. Queues managed with `cas2` instructions are useful for communication between non-maskable interrupt service routines and other code.

If devices must share interrupt priority levels, vectored interrupts can give them separate vectors. When the processor receives a vectored interrupt, it asks the device which vector number it should use. The hardware that caused the interrupt responds with an 8-bit number which is interpreted as a vector number. The vector selected by the device is picked out of the vector table. There are 192 vectors in the table just for vectored interrupts.

Vectored interrupts require more sophisticated hardware than autovectored interrupts, but they can give faster response. If several devices share a priority level and use autovectored interrupts, each time there is an interrupt OS-9 has to determine which device caused it. If there are enough devices in a system, even vectored interrupts eventually leave two devices on the same vector, but 192 vectors leave more room than seven vectors.

18.1 Polling

Some operating systems (e.g., CP/M) use a technique called polling, or force user programs to poll for themselves. In these systems, each piece of hardware that might need attention is polled (or checked) at frequent intervals. In a system with a printer on a parallel port and a terminal on a serial port, the overhead involved in polling the I/O devices isn't too much. The serial port needs to be checked a few thousand times per second; the printer (being a slow output device) can be polled much less frequently—two hundred times per second should be enough for an ordinary dot-matrix printer. When a program is running, it must take responsibility for any polling. There is no automatic way for the operating system to take over at intervals.

18.2 The Alternative

Under OS-9, interrupts are precisely a way for the operating system to take over when it is required. I/O ports are programmed to produce an interrupt every time they need attention. When the interrupt is received, OS-9 is given control of the machine to service the interrupt. Since an interrupt is only generated when something actually needs doing, there is no need to watch for devices that need service. Neither user programs nor OS-9 need to poll constantly.

The most important result of the use of interrupts is that I/O is simplified for users. OS-9 deals with all I/O hardware. If a program isn't ready for input when a byte arrives, OS-9 holds it in a buffer until the program requests it. Similarly, OS-9 maintains a buffer of characters ready for output if a program is producing output faster than the output device can take it.

18.3 Multitasking and the Clock

OS-9 multitasking capability is also based on interrupts. I/O hardware may produce frequent interrupts in an OS-9 system, but they can't be relied on. Minutes might pass without a single I/O operation. To insure that OS-9 gets control at frequent intervals, almost all OS-9 systems include a ticker, a special device that produces interrupts. These interrupts are raised ten to a hundred times per second, depending on the system.[1] OS-9 uses the timer interrupt as a trigger for its housekeeping operations. When several processes are running, OS-9 switches the current process off and starts another every few clock ticks (different numbers of ticks for different systems).

Switching from one process to another several times per second makes it possible for OS-9 to appear to run several programs at the same time. If you were a very fast-moving house painter, you could work on all four walls, moving quickly around the house. If you moved fast enough, a spectator might think that four painters were working slowly, one on each wall.

The timer is also used to support time-dependent kernel services: alarms and timed sleeps.

18.4 The Polling Table

When an interrupt is raised, OS-9 only knows that something on that vector needs attention. It has a list, called the polling table, of every device that might cause an interrupt. For each interrupt, OS-9 runs through the table checking each device on that vector to see if it sent the interrupt. This is classic polling and involves overhead in

[1]Timer interrupts are almost always generated at 100 interrupts per second.

that it doesn't go directly to the source of the interrupt. The advantage OS-9 has over other operating systems that use polling without interrupts is that OS-9 only needs to poll when something needs attention.

The first entries in the table get slightly faster service than later entries. Devices that need extra fast service can force themselves to the beginning of the table by requesting a high priority[2] when they enter themselves in the table. The F$IRQ service request is used to update the table. Check the example device drivers in chapters 29 and 30, and appendix D for samples of the F$IRQ SVC in action.

18.5 Non-Polled Interrupts

The F$FIRQ system call installs fast but restricted interrupt service routines. OS-9 allows at most one FIRQ per interrupt vector, and the interrupt service routine (ISR) must return with all registers except CCR, D0, and A2 unchanged. If a fast ISR returns with carry set, OS-9 will pass control to any ordinary interrupt service routines attached to the vector.

Superficially, F$IRQ and F$FIRQ are nearly identical. The parameters passed to F$IRQ are:

d0.b	Vector number
d1.b	Priority
a0	ISR entry point address
a2	Passed to ISR; customary static storage pointer
a3	Passed to ISR; customary port address

For F$FIRQ the parameters are:

d0.b	Vector number
d1.b	Must be zero
a0	ISR entry point address
a2	Passed to ISR; customary static storage pointer

For both types of interrupt service routine, the routine is passed the vector offset of the interrupt in D0, the value assigned to A2 when the ISR was installed, and a pointer to system globals in A6. Only F$IRQ service routines get a meaningful value in A3. F$FIRQ routines need to discover the port address another way:

- The port address can be passed in A2. This is fast and flexible, but leaves no obvious way to pass a static storage address to the ISR.

[2]A high priority in the polling table is signified by a *low* priority value.

- The normal way to pass a port address to the ISR is by saving it in "static storage," the data pointed to by A2.

- The port address can be a constant value built into the ISR. Drivers written this way are not as easy to reuse as drivers that are more parameterized, but "hard coded" addresses are easy to use and the code executes quickly.

- OEM globals are available through the system globals pointer in A6. If you can locate a field in OEM globals that you can dedicated to the ISR, it is a good place to pass any data between the ISR and other code.

18.6 Masking Interrupts

Sometimes a block of instructions must be executed without interruption. This is almost never a concern for regular programs, but for parts of OS-9 it is crucial. When a device driver is in the middle of updating a queue, it can't tolerate anything writing to the same queue. This is an example of a *critical section*: a block of code that must have exclusive access to some resource.

The most elegant way to protect a sequence of instructions is with the 68000 instructions that read, modify, and write memory all in one instruction. These instructions can't be interrupted even by a separate processor or DMA hardware. They are `tas` on all the processors in the 68000 family, and `cas` and `cas2` on the 68020, 68030, 68040, and other related processors. None of these instructions mask interrupts, but they do modify memory without leaving an opening for an interrupt or even access by another processor that shares the same memory. `Tas` is usually used for synchronization, `cas` for singly-linked lists, and `cas2` for doubly linked lists. These special instructions are the easiest way to handle memory that can be written by more than one processor.

If only one processor can access memory, every instruction is indivisible, but often no single instruction is enough. masking interrupts is an easy way to protect instruction sequences. (Only system code can mask interrupts.) The system byte in the status register contains a three-bit interrupt mask. This mask can be used to mask out all interrupts whose priority level is not greater than the mask's value. For example, if the interrupt mask has the value binary-101, interrupts at priority level five and down will wait. Setting the interrupt mask to 111-binary blocks all but non-maskable interrupts. Since non-maskable interrupts should only be generated in case of an emergency, code protected by an interrupt mask of %111 can be considered non-interruptible most of the time.

The sequence is:

```
move.w  SR,–(SP)       Save SR
ori     #$700,SR       Set interrupt mask
...
move.w  (SP)+,SR       Restore SR from the stack
```

The ellipses (...) represent instructions that can't be interrupted except by a non-maskable interrupt (NMI) or reset (this section of code is a critical section). If you must use this trick, keep the number of protected instructions to a minimum. When interrupts are masked, OS-9 can't service interrupts. I/O comes to a halt. In some systems, even the real-time clock falls behind.

Device drivers mask interrupts to the interrupt level of their device when they access data structures that are shared between their interrupt service routine and their mainline. The kernel masks interrupts all the way to level seven when it executes code that must not be interrupted by any interrupt service routine. Masked interrupts are a necessary evil. The kernel masks interrupts as seldom as possible and device drivers should be similarly careful. Masked interrupts add to interrupt response time, and excessive interrupt masking ultimately causes poor I/O performance.

18.7 Floating Point

OS-9 does not give interrupt service routines a "floating point context." This means that an ISR must not casually use floating point instructions. The best advice is to avoid floating point operations in ISRs except in deperate situations. Most floating point instructions are slow compared to other instructions, and the support code required for floating point instructions in an interrupt service routine roughly doubles the setup time for the ISR. If floating point calculations must be done in the ISR, it is responsible for all FPU management.

The ISR must include a FPU prolog and epilog:

```
* Prolog
            fsave      –(sp)
            fmovem.x fp0–fp7,–(sp)    only save the registers actually used
            fmovem.l fpcr/fpsr/fpiar,–(sp)


* Epilog
            fmovem.l (sp)+,fpcr/fpsr/fpiar
            fmovem.x (sp)+,fp0–fp7
            frestore (sp)+
```

A 68020 or 68030 with a math coprocessor can use floating point in interrupt service routines as can a 68040 with ***fpsp***. A 68040 using ***fpu040*** to fill the gaps in its floating point instruction set should *not* use floating point instructions in an interrupt service routine.[3]

[3] If an ISR is the only entity in a system that uses floating point services, it can discard the floating point prolog and epilog and should even work with ***fpu040***.

Chapter 19

The RBF Disk Format

This chapter discusses the way OS-9 structures data on disks. It takes a low-level look at file allocation and directory structures.

Formatting a disk changes it from a piece of iron-oxide-coated mylar or metal into a carefully organized empty file structure. There are some features of formatted disks that are common across all hardware and operating systems.

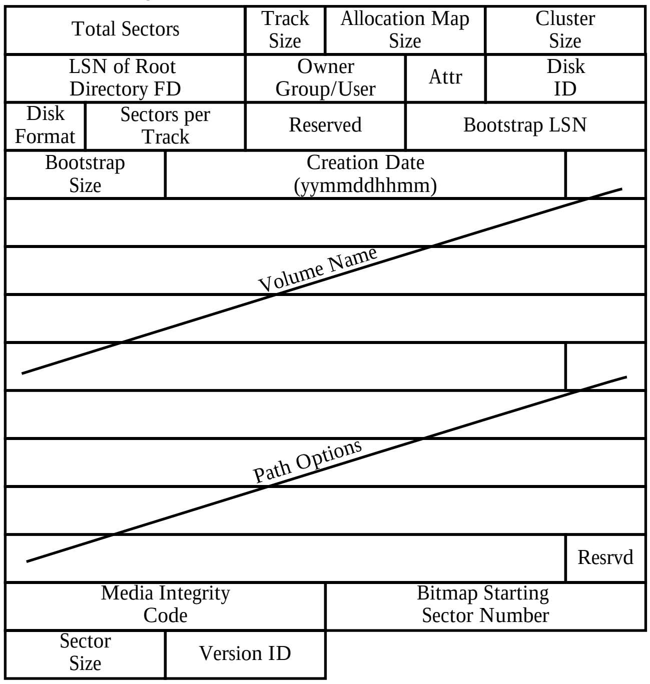
Information is recorded on the surface of a disk. Some drives only use one side of the disk, others have a read/write head on each side of the disk so they can use both surfaces. Hard disks may be built of two or more platters turning on the same spindle. Hard disks, and some mutated versions of floppy disks, may have more than two sides. Three platters offer six sides (though only five are usually used for data).

A disk's surface is divided into tracks, which are concentric circular paths around the disk reminiscent of the grooves in a phonograph record. The number of tracks depends on the quality of the disk drive. The more tracks, the more data can be stored on the disk, and the more precision the disk drive must have to position the head over a track. Low-performance floppy disk drives can only handle 35 tracks on a disk. High-performance hard disk drives may support more than 1000 tracks.

Each track is divided into sectors. These sections of the track are the pigeon holes where data is stored. The data part of each sector is surrounded by timing and identifying bytes. These bytes help the disk controller find a sector for which it is searching. The timing bytes around each sector leave the controller time to recognize a sector and respond.

The number of sectors on a track varies widely depending on the sector size, the size of the disk, and the recording density that is used. The smallest number of sectors per track currently being used is ten 256-byte sectors for single density five-and-a-quarter inch and three-and-a-half inch disks. Eight inch double density disks have twenty-eight 256-byte sectors per track. Extra density three-and-a-half inch disks have

Figure 19.1: Disk ID Sector Format



thirty-six 256-byte sectors per track. Hard disks may have 50 or more sectors per track depending on the controller you use and the sector size.

19.1 The Identification Sector

After we get above the level of the physical disk, all OS-9 disks have the same characteristics. Information about the disk as a whole is stored in its first sector, that is, the first sector on the first track. The sector containing this information is called the "identification sector." The information in the identification sector includes the specifications for the way the rest of the disk is written, the location and size of the bootstrap (if it's there), the name and creation date of the disk, the user and group of the owner of the disk, and a pointer to the root directory.

One of the fields in the identification sector is DD_BIT. This field indicates the number of sectors in a cluster. For most systems this will be one, but if your disk is exceptionally large, DD_BIT can be made greater than one. (DD_BIT can take any power of two that will fit in a 16-bit word.) A cluster is the unit of allocation for disk space. Cluster size must be considered when a large-capacity disk is formatted. It can also be used for some subtle performance optimization.

An OS-9 disk can be formatted with as many as 524,288 clusters. When a disk is formatted, the number of sectors per cluster must be chosen such that the number of sectors on the disk divided by the number of sectors per cluster is no greater than 524,288.

As a general rule, clusters should be no larger than necessary. Files seldom exactly fill the clusters that are allocated to them, and the empty space at the end of the last cluster is wasted. The smaller the clusters, the less space is lost at the end of each file. For example, one-hundred 100-byte files actually contain 10,000 bytes of information. With 256-byte sectors and one-sector clusters the files consume a total of 25,600 bytes on disk plus another 25,600 bytes for file descriptors (see section 20.2). With four-sector clusters the files consume 102,400 bytes for the files (RBF squeezes the file descriptors in with the files). Sixty-five percent of those 102,400 bytes are unused.

Large clusters are not all bad. First, many files on a typical hard disk are a thousand bytes or larger. The wasted space from large clusters is not so bad with reasonably large files. Large clusters can also improve disk performance. A cluster represents a group of contiguous sectors on the disk. These sectors are placed so they can be read one after the other as quickly as possible. The cluster size sets a maximum on the disk fragmentation. If you are willing to trade some disk space for performance, larger clusters are worth trying.[1] (See section 20.6 for more discussion of cluster size and performance.)

19.2 The Allocation Map

The sector right after the identification sector contains the beginning of the disk allocation map. This is an array of bits indicating whether each cluster on the disk is allocated or free. If the bit corresponding to a cluster is one, the cluster is allocated; if it is zero, the cluster is free.

Disks with bad sectors will show allocated clusters that are not contained in any file. RBF does not have any special way to mark bad sectors, so they are just marked "allocated" in the disk allocation map. ***Dcheck*** will complain about these clusters, saying that they are allocated but not in any file. In this case, that is fine. Don't let ***dcheck*** "fix" those clusters.

The disk allocation map is used whenever a file is created or deleted, or when the size of a file is changed. In each of these operations disk space is used or freed. The disk allocation map contains the location of each free cluster on the disk.

[1] After considerable research, the BSD development team decided that four kilobytes was the best cluster size for the Berkeley fast file system, but they have a trick that allows a file to use part of a cluster.

19.3 The Root Directory

One of the fields in the identification sector is a pointer to the root directory. Every RBF disk, even those on which you never create a directory, has a root directory which is named after the device holding the disk; i.e., if you do a directory command on /d0 the result will be a list of the files in the root directory for /d0, and if you move the disk into drive one, the same directory will appear as ***dir*** /d1. The directory linked to the identification sector is called the root directory because if you view the directories on a disk as forming a tree, the root directory is at the base (or root) of the tree.

The root directory, like every other OS-9 directory, is a file of directory entries, each entry consisting of a 28-byte file name, one empty byte for alignment, and the three-byte logical sector number of the file descriptor for the file. The first directory entry has a file name of `.` (that's a single dot) and points to the file descriptor for the directory itself. The second directory entry has a file name of `..` (two dots) and points to the file descriptor for the parent of the directory. The root directory has no parent, so the `..` entry in the root directory points to the root's file descriptor. Because of this, a command like "chd `........`" doesn't fail if you use too many dots. It just reaches the root directory and stays there.

A directory may contain empty directory entries. When a file is deleted, the directory entry is marked "empty" by writing a $00 as the first byte of the file name. The directory file is never shortened, so after many files are deleted from a directory, a dump of the directory file will show a long list of empty entries.

A directory file has a special purpose, but it can be read or even written much like any other file. RBF only insists that the program must know it is accessing a directory. The open-mode parameter must specify directory access mode whenever a program attempts to open a directory file, otherwise the open will return an error.

Directory files should only be written to with great caution, but reading them is harmless. A directory file can be examined with ***dump***.

```
$ dump .
```

The result is a dump-format listing of the working directory.

19.4 The File Descriptor

0	Attributes	Group	User	Year Modified
4	Month Modified	Day Modified	Hour Modified	Minute Modified
8	Link Count	File Size in Bytes		
C	File Size (continued)	Segment List ...		

Directory entries don't point directly at files. They point at file descriptor sectors which give all the information about a file except its name and the directory it's in. The most interesting result of keeping most of the information about a file out of the directory is that a file can be renamed, moved about, and even given aliases (alternate names) without special effort.

Think about what would happen if two directories had entries pointing to the same file descriptor. The file could be accessed under two names from two separate directories. This kind of trickery upsets some OS-9 commands, notably ***dsave***, but in most cases OS-9 handles it smoothly. There is even a field in the file descriptor that can be used to give the number of directory entries pointing to it. A file's space allocation won't be returned until this counter is zero.

Microware currently doesn't support multiple links to files at the utility-program level because multiple links make it difficult to keep the disk structure consistent. It is possible to support multiple links to files and ensure file system integrity, but that cannot be done to RBF without undesirable side effects. The usual compromise that permits multiple links is to accept that there will be occasional disk problems, and patch the problems when they show up. So far Microware has chosen not to do this under OS-9.[2]

19.5 Raw Disks

The super user can skip around all the structure that RBF imposes on a disk, and access the entire disk as a simple array of bytes. Any process can open a *raw* device and see the disk as a single unstructured file, but only the super user can read beyond the allocation bit map, and only the super user can write to the raw device.

A raw device can be addressed by name:

- /d0@ names the raw disk in device /d0.
- /h0@ names the raw disk in device /h0.

Raw devices can also be allowed to default. Opening the file named @ for read or write opens whatever device holds the default data directory. Opening @ for execution opens the device that holds the execution directory.

Careful access to the raw device is useful. It is the best way to access a corrupted disk and make repairs. It is a good way to quickly copy one disk to another (e.g., the ***backup*** utility), or to create a file that will be an image of the raw disk. And it is the only way to get away from RBF's careful control of writes to FD sectors, or to directly read and write sector zero or the disk allocation map from a program.

[2]There are numerous utility programs circulating in the OS-9 community that take advantage of multiple links. RBF seems to deal with multiply linked files correctly.

Table 19.1: Specified Fields in the Universal Disk Format

Device Descriptor Option	Value
PD_TotCyls	80
PD_CYL	79
PD_SCT	16
PD_DNS	MFM and 96 tpi (135 tpi on 3in disks)
PD_SOffs	1
PD_TOffs	1

Programs should access a raw device carefully. Although the raw device overlaps every file on the disk, RBF ignores that fact. It treats the raw device as a separate file for purposes of record locking. Nor does RBF take note when an application writes FD or directory information on a raw device.

One other useful application of raw device access is benchmarking. A program that reads a raw disk pays little RBF overhead. Consequently, reading several hundred kilobytes from a raw device is a good measurement of hardware and driver speed.

19.6 Disk Drive Incompatibilities

Once, all OS-9 disks were readable with standard device descriptors on any drive that was physically capable of reading the data. That time is past.

All OS-9 disks had track zero formatted single density. Thus, a disk driver could configure itself for single density and read sector zero on track zero. Sector zero gave it the disk's disk ID sector, which contains enough information about the disk format that the driver could initialize the driver's drive table entry and configure itself to read or write the rest of the disk.

Two hardware problems were enough to end the old universally usable format. Some disk controllers were unable to deal with disks that numbered sectors starting at zero, and some disk controllers were unable to read track zero at single density.

19.6.1 The Universal Disk Format

The sector base offset field instructs drivers to convert the zero-based logical sector numbers used by RBF into physical sector numbers offset such that they start at one (or some other number noted in the sector base offset field). The universal disk format avoids special cases by not using any part of the disk that may be unreachable or has special meaning to any known controller. The universal format jumps over the first track on the disk and numbers sectors starting at one. The universal disk format also specifies the recording format on the other tracks (see table 19.1).

If you use floppy disks primarily to exchange data with other systems, you should default to universal format. Every OS-9 system with at least an 80-track floppy drive should be able to communicate with you. Any floppy controller can handle universal format disks, and more capable disk drives can degrade themselves by tricks like double-stepping to read and write universal format.[3]

19.6.2 Foreign Disk Formats

Universal format is not yet a widely-enough used standard. It is a prudent disk format to use if you plan to send a disk to someone with a system unlike your own, but the restriction on tracks and density may be uncomfortable if you have a disk drive that can use much higher densities.

RBF and the RBF drivers automatically adjust to many disk configurations. The disk ID information in sector zero lets the driver adjust its understanding of the disk format invisibly. This only fails when the driver encounters a disk outside the range of variation it expects.

If you receive a disk that you cannot read, investigate the following:

- Do you have a file manager that is compatible with the disk? There are many more disk formats than RBF's and PCF's. If you don't have the right file manager you may be able to dump the raw disk and sort what you need out of the resulting mess, but it is generally enough reason to look for someone with the right file manager.

- Can your hardware handle the disk? The disk might be higher density than your drive can read. The disk could also be recorded with constant linear velocity (like a CD-I disk) instead of the more traditional constant angular velocity. That's a good reason to search for someone with compatible hardware.

If your hardware and file manager are ready for the disk, the next step is to create an experimental device descriptor based on your existing descriptor for the device you mean to use to read the foreign disk. If you can talk to the person who formatted the disk the descriptor-generation job is easy: build a new descriptor whose options section matches as nearly as possible the options section of the disk creator's descriptor.

For experimentation purposes start by attempting to dump the disk in "raw" format:

```
$ dump /d0@
```

[3] If you have only a 40-track drive, or a controller or drive that only accepts single density, you are out of universal format's space.

The most likely error while reading foreign OS-9 disks is invalid sector number. Try using a different value of sector base offset or track base offset.

If you can dump the disk, examine sector zero. That sector contains enough information to construct a good device options section.

Once you have the descriptor configured well enough to read sector zero (which is usually a matter of getting the track zero density and the sector base offset set correctly), you should be able to read the rest of the disk.

Remaining problems often fall into one of the following classes:

- Specifying too many sectors per track gives bad sector number errors.
- Specifying too few sectors per track can cause the driver to skip the sectors that are "not supposed to be on the track."
- Getting the number of sectors per track right for track zero is not enough. The rest of the tracks may need a different value. The wrong number of sectors on track one can cause data skipping or bad sector numbers further out in the disk.
- Specifying double stepping for a single-stepped disk, or specifying single-sided for a double-sided disk will cause the driver to attempt to skip half the data on the disk.
- Creating a modified version of a device descriptor only works if the old descriptor is removed from memory by ***deiniz***'ing it until ***devs*** no longer shows that device. After the old device descriptor is removed, the new descriptor may be loaded and ***iniz***'ed. Failing to completely remove the old descriptor causes the new descriptor to have no effect.

It may take up to a half hour to fiddle with a device descriptor until it can read an unknown disk, and occasionally the disk will be beyond what you can accommodate. If you send a disk to someone, it is friendly to send enough information with the disk to build a descriptor for it. It is even more friendly to use universal format.

Chapter 20

Managing Disks

Disk space is another kind of memory the OS-9 programmer might need to help OS-9 manage. This chapter discusses how to use disk space efficiently—or at least know when you're using it inefficiently. It also discusses things that can slow down access to disk files and some tricks for recovering damaged or deleted files.

Two types of files make inefficient use of disk space: small files and unexpectedly large files.

20.1 Using Space Efficiently

Small files carry a heavy overhead burden compared to their size. The directory entry is a barely noticeable 32 bytes. The file descriptor takes a sector (often 256 bytes). The data takes at least a sector. A file with just one byte in it uses 544 bytes of disk space. Often it is easier to have a few small files than one large one, but balance easy programming against wasted disk space. If you have a choice of many small files or fewer large ones, choose larger files when efficient use of disk space is your first priority. Don't, for instance, use a directory as a telephone directory for a large organization. Letting the file name be the person's name and the contents of the file be the telephone number is easy. The entire system can be constructed from OS-9 utilities. But, at 544 bytes per member, about 1,200 entries fill an 80-track floppy.

A program can accidentally increase the size of an RBF file without any ill effects other than wasted disk space. All it has to do is write a byte at a position beyond the end of a file and the file will be lengthened to include that byte. If you aren't careful, that trick can cause you to allocate more space for a file than it needs. If a file seems remarkably large, check the programs that update it for seek errors.

20.2 Disk Access Speed

The speed of RBF is chiefly influenced by the speed of the I/O hardware, the amount of multi-sector I/O that is done, the number of times data must be copied, the effectiveness of disk caching, and the appropriate choice of the sector interleaving factor.

The speed of the hardware is not a software issue, but it is a limiting factor. Ultimately, it is impossible to move data to and from a disk faster than the speed of connection from memory through the controller and the drive's electronics and mechanism.

OS-9 isn't known for its high-speed disk access, though access to a file is seldom significantly slower than for any other operating system on the same hardware.[1] The most common cause for slow access to files is the environment; that is, what other files are being accessed and what processes are running. After a disk has been in use for a long time, disk fragmentation breaks files into pieces scattered over the drive. Fragmentation can cause serious disk performance problems when a disk is nearly full and has been used heavily with a typical work load (editing, compiling, downloading files, and other activities that create and delete files).

It takes time to move a disk drive's read/write head from track to track on a disk. Because of this, it is fastest to access a file with the minimum movement of the heads. The disk organization that OS-9 uses is flexible and safe, but it can generate extra head movement.

Before reading a file, OS-9 must read the directory to find the address of its file descriptor. Then it must read the file descriptor. The file descriptor contains a list of address/length pairs that describe the location of the file on the disk. The file descriptor for an open file is stored in memory attached to the path descriptor. If a file's directory entry is located near the beginning of the directory, the file can be read with only two extra reads: one for the directory entry, the other for the file descriptor.

The maximum segment size is the lesser of 32 megabytes or $8CS^2$ where S is the sector size and C is the number of sectors in a cluster. On my hard disk that comes to four megabytes per segment. The second limit comes about because RBF insists that all the clusters in a segment are represented in one sector of the disk allocation bit map. Segments seldom reach this limit. On a fragmented disk, a segment is likely to get substantially less than a full sector of the allocation map.

Since RBF expands the segment list to fill an FD sector, a file on a disk with 256-byte sectors has room in each file descriptor for 48 segment descriptors, and 512-byte FD sectors can reference up to 99 segments. Each segment is described by a starting logical sector number and a length stored in the file descriptor. A file may use more

[1] OS-9 actually has rather fast disk I/O when compared to other operating systems running with similar I/O hardware. There is an important extra cost when disks are written in that OS-9 always updates the disk immediately. Great care is taken to protect the integrity of the disk.

than one segment because it is too long to fit in one segment. It may also use multiple segments because the file grew each time it was written, and RBF found that its last segment was blocked by another file, or because there were not contiguous blocks of disk space long enough to hold the entire file. Files that use more segments than the minimum number required for their size are a signal that the file system is becoming fragmented. Fragmented files require extra seeks to move the head from one segment to another.

The only utility Microware provides to deal with fragmentation is ***copy***. Copying the contents of a disk file by file from one disk to another or from place to place on a single disk leaves the file in one piece if the disk has enough contiguous free space to hold the file. Using ***backup*** doesn't help because ***backup*** makes a mirror image of the disk; each fragmented file is just the same on the new disk as on the old.

20.2.1 FDList

Running *fdlist* (see section 20.12.1) against the file containing the text for this chapter gives the following output:

```
Owner Grp.User: 1.1
File Size: 38080 bytes (37.19k)
Attributes: ------wr
Creation Date: 91/9/23
Last modified: 91/10/6 16:57
(start: $212cd, len: 1)  (start: $2183c, len: 74)
```

This shows that the file is not badly fragmented. It has a segment containing one sector, and another segment containing the rest of the file. The output of:
$ dir -e disk.tex

```
 Owner   Last modified  Attributes Sector Bytecount Name
-------  -------------  ---------- ------ --------- ----
  1.1    91/10/06 1657   ------wr   212CC     38080 disk.tex
```

shows that the FD sector for disk.tex is located in the sector before the first data sector for the file. This indicates that they are sharing a cluster.

20.3 Multi-Sector I/O

For ordinary I/O, control passes from RBF, down through the device driver, and back into RBF for each sector. That trip is slow in any case and if it causes the sector interleaving factor to change, it can seriously hurt performance. If it *should* cause the interleaving factor to change but does not, performance will really turn to mush.

Many disk drivers now support multi-sector I/O. This facility lets RBF request a contiguous sequence of disk sectors in one request to the driver. For instance, RBF might request 32 sectors starting at sector 1368, and the driver would deliver them all without further direction from RBF.

20.4 Direct I/O

Buffered I/O is staged through the file manager and the device driver. For instance, a buffered read copies a sector of data from the disk to the buffer attached to the path descriptor. Then the data is copied from the path descriptor buffer to the user's buffer. If the requested data spans more than one sector, the driver is then called to read another sector into the path descriptor buffer, and that is copied and the iteration continues until the requested number of bytes has been copied.

RBF runs much more quickly when it can avoid buffering data in the path descriptor and let the driver access the calling process' buffer directly. It can do that provided the following two conditions are met:

- Direct I/O only works for full sectors of data. This does not mean that the I/O operation must start on a sector boundary and copy an integral number of sectors. RBF buffers partial sectors at the beginning and end of a read or write and lets direct I/O operate on the sectors in the middle.

- The user's buffer must be word aligned. This is a conservative restriction on RBF's part. Some DMA controllers cannot handle unaligned memory. The buffer attached to the path descriptor is always at least 16-byte aligned, so all DMA devices can read or write that buffer, but there is no rule that forces user buffers onto a word boundary, so some DMA hardware fails for some user buffers. In practice, unaligned buffers are rare so RBF and PCF simply check the alignment of addresses passed to them, and buffer I/O to unaligned addresses. RBF and PCF do not have special code to take advantage of the rare DMA controllers that can handle odd addresses.

Direct I/O to the user's buffer is a big performance boost. By itself, it can provide nearly a factor of two improvement. Together with multi-sector I/O, it may improve performance by around a factor of eight for some hardware.

Direct I/O and multisector I/O have the strongest effect when large blocks of data are read or written. If there is sufficient RAM, programs can get an excellent performance boost by reading and writing entire files in one operation:

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

```
#include <modes.h>
#include <errno.h>
#include <const.h>

/*
    Prototypes
*/
u_int32 readit(char *, char **);
char *writeit(char *, char *, u_int32, u_int32);

u_int32 readit(char *name, char **buffer)
{
    u_int32 size, n;
    path_id path;

    if((errno = _os_open(name, FAM_READ, &path)) != SUCCESS)
        return –1;
    if((errno = _os_gs_size(path, &size)) != SUCCESS){
        (void)_os_close(path);
        return –1;
    }

    if((*buffer = malloc(size)) == 0){
        (void)_os_close(path);
        return –1;
    }
    n = size;
    if(((errno = _os_read(path, *buffer, &n)) != SUCCESS) ||n != size){
        (void)free(*buffer);
        (void)_os_close(path);
        return –1;
    }
    _os_close(path);
    return size;
}



char *writeit(char *name, char *buffer, u_int32 size, u_int32 perm)
{
    u_int32 n;
    path_id path;

    if((errno = _os_create(name, FAM_SIZE |FAM_WRITE |FAM_SIZE, &path,
            perm, size)) != SUCCESS){
```

Table 20.1: Supported Sector Sizes

Size	RBF	Hardware
256	X	X
512	X	X
1024	X	X
2048	X	X
4096	X	X
8192	X	
16384	X	
32768	X	

```
        return NULL;
    }

    n = size;
    if(((errno = _os_write(path, buffer, &n)) != SUCCESS) ||n != size){
        (void)_os_close(path);
        return NULL;
    }
    (void)_os_close(path);
    return buffer;
}
```

20.5 Sector Size

RBF supports several sector sizes (see table 20.1). If the disk driver and hardware also support a variety of sector sizes, you can choose a sector size that tunes your disk performance to your needs.

Sector size is a tradeoff between disk space and speed. In general, I/O speed increases with sector size, but two sectors (one sector for the file descriptor and one for data) is the minimum allocation for a file, and one-thousand 50-byte files in 4096-byte sectors waste about eight megabytes of disk space. This kind of profligate waste of disk space may also hurt performance. Disks work fastest when they don't need to seek, and seeks are minimized when as much data as possible is placed on each cylinder. Large amounts of empty space push data onto other cylinders.

Choice of the optimum sector size requires tests with the specific set of files and applications that should be optimized, but there are some useful rules of thumb:

- If you use large files and read and write large buffers, the best sector size is

Figure 20.1: C Code to Change I/O Buffering

```
Resize(FILE *file, u_int16 size)
{
    /* Call this function after the file is opened but before any */
    /* other operation is performed on the file */
    if(size <0){
        fprintf(stderr, "Resize called with size less than 0 (%d)\n", size);
        exit(errno);
    }
    if(setvbuf(file, NULL, _IOFBF, (size_t)size) != SUCCESS){
        fprintf(stderr, "Failure in setvbuf\n");
        exit(1);
    }
}
```

generally the one that fits the most data on the disk. This transfers the most data per rotation of the disk.

- It is fairly easy to use the output of ***dir -er*** to calculate the amount of disk space a particular set of files will waste with a particular sector size. (See section 20.12.2.)

- If most of your programs are in C (as are most of the important Microware utilities, like the C compiler), reads and writes use 512-byte buffers. You can change the I/O buffer size for C's I/O library (see figure 20.1), but unless the buffer size is changed, only 512- and 256-byte sectors give good performance. Larger sector sizes cannot use direct I/O.

- Large sectors are an easy cure for error 217 (segment list full). A 256-byte sector holds a file descriptor with room for 48 segments, but 512-byte sectors give each file descriptor room for 99 segments. The more segments a file descriptor can describe, the less likely error 217's are.

- Large sectors also increase the maximum possible file size. Since increased sector size increases both the number of segment descriptors in the FD and the maximum number of bytes in each segment, doubling the sector size quadruples the maximum file size.

The easiest rule of thumb is to use 512-byte sectors for hard disks.

20.6 Allocation Units

The number of sectors per cluster is set when a disk is formatted. The command:

```
$ format –c=4 /h0fmt
```

formats /h0fmt with four sectors per cluster. Cluster size does not affect direct I/O, but it does affect disk fragmentation and may limit the use of multi-sector I/O. Like large sectors, however, large clusters probably waste disk space.

Clusters containing 1024 bytes are a good size for general use on large hard disks. This guarantees that multi-sector I/O can always transfer at least one kilobyte per operation (more if the file isn't fragmented) and it doesn't waste much disk space with a collection of files typical for programming and word processing work. With 512-byte sectors, and two sectors per cluster, the two-sector minimum allocation[2] for a file fits neatly in a cluster.

Segment allocation size is specified by the PD_SAS field in the path descriptor. Large values of PD_SAS are good for performance. They improve multi-sector I/O by decreasing file fragmentation, and large values of PD_SAS do not generally cause wasted disk space. If you have plenty of disk space, set PD_SAS to at least a track—perhaps as much as a cylinder, but in most cases a track is a good value.

A non-obvious use of PD_SAS is to set the minimum directory allocation. Sectors allocated to directory files are not released until the directory is deleted, consequently directory files are allocated some multiple of PD_SAS sectors.

Programs that have trouble with error 217 (segment list full), should set the file size when the file is created—if they can. If that isn't an option, use a very large value of PD_SAS for that file. A file is given the initial allocation specified in PD_SAS and keeps that allocation until it either grows beyond it or the file is closed with the file position at the end of the file. If a file is closed with the file position at the end of the file (the normal state after a file is written sequentially), any unused clusters at the end of the file will be freed.

20.6.1 A Case Study

The program ***diskspace*** (found in section 20.12.2) accepts the output of ***dir –ear*** (filtered through several instances of ***grep***) as input and generates an estimate of the disk space used by the particular files it encounters under various combinations of sector size and cluster size.

On my main hard disk, this program yielded table 20.2. I chose 512-byte sectors and two sectors per cluster. That uses 106% of the space I would have used with 256-byte sectors at one sector per cluster. On my hard disk that is trivial space overhead.

[2] A file descriptor sector and a sector for data.

Table 20.2: Disk Space Efficiency
The disk contains 98910320 bytes of data or directory storage.
There are 9323 files and directories on the disk.

Sect Size	Sect/ Clus	Data Space	FD Space	Overhead
256	1	97755.5k	2330.8k	0%
256	2	98838.2k	2330.8k	1.08%
256	4	101278.3k	2330.8k	3.52%
256	8	106737.3k	2330.8k	8.97%
512	1	99003.5k	4661.5k	3.58%
512	2	101076.5k	4661.5k	5.65%
512	4	106010.5k	4661.5k	10.58%
512	8	117810.5k	4661.5k	22.37%
1024	1	101592k	9323k	10.82%
1024	2	105261k	9323k	14.49%
1024	4	115845k	9323k	25.06%
1024	8	141813k	9323k	51.01%
2048	1	107246k	18646k	25.78%
2048	2	113258k	18646k	31.79%
2048	4	137242k	18646k	55.75%
4096	1	119880k	37292k	57.04%
4096	2	129996k	37292k	67.14%

Even four 512-byte sectors per cluster would have been quite reasonable, but it would be hard to convince me to use eight sectors per cluster.

Sectors bigger than 512-bytes use too much space for their FD sectors. The 99 segments provided by 512-byte FDs are sufficient for all but exceptionally-fragmented disks. Taking that view, sectors greater than 512 bytes waste a great deal of space on FDs. For instance, 4096-byte sectors would "waste" about 32 megabytes on my disk.

Throughout the table, going from one-sector clusters to two-sector clusters has a comparatively small penalty. The minimum allocation of one cluster per file, or one sector for data and one sector for the FD causes this. Since every small file (with no more than one sector full of data) uses two sectors in any case, they don't bear any additional cost from a two-sector cluster size.

20.7 Disk Layout

If optimization is very important, the directory entries for the most critical files should be placed early in the directory; otherwise several sectors of directory may have to be read before the right entry is found. This trick is most useful in the execution directory. There are many entries in that directory, and most of the files are small enough that a few extra reads to search through the directory increase the time required to read the file by a noticeable proportion.

For maximum speed, put your most-used files near the beginning of the directory.[3] The best way to do this is to start with an empty directory and copy files into the directory in the order you wish them to appear.

20.8 Disk Caching

RBF disk caching is very useful with floppy disk drives and other slow devices. Its benefits are most obvious with programs that use directories heavily like ***dir***, ***make***, and ***dsave***. It has little influence on programs that chiefly use large reads and writes.

The size of the cache is set when the cache is enabled, but it is always at least ten kilobytes. The cache is basically a write-through cache with least-recently-used aging. It has two special features that adjust it to RBF: directory data is aged half as fast as other data, and read requests for more than two sectors do not use the cache. Long reads work well from disk. Furthermore, reading a single moderate-size file would flush everything else out of the cache if long reads did not bypass the cache.

[3] The ***dir*** command can be deceptive. It normally sorts the directory entries. The result is a list of file names that has no relation to the actual order in the directory file. Use ***dir –s*** to see the true order of a directory.

The cache's write-through design does not perform as well as a more aggressive caching strategy would, but it is robust. Disk caching can be turned on and off at any time without special ceremonies (like ***sync sync sync***).

A small cache accelerates directory operations nicely on a slow disk drive. A large cache dramatically decreases disk access during typical program development. A disk cache is most effective when combined with defs and libs on a RAM disk.

In systems with light disk contention, high-performance disk drives are barely slower than the disk cache and they use no system RAM. Disk caching offers comparatively small performance improvement with high-performance disk drives, but this is balanced by the comparatively heavy use that high-performance disks get. Even very fast disks in active use on a multi-user system usually respond well to a large disk cache.

Time spent searching a very large cache can cause the cache to hurt I/O performance. Like many tuning decisions, the best approach is experimentation. Some interesting configurations are:

- No disk cache and a RAM disk big enough for temporary files.
- The smallest supported disk cache, ten kilobytes, and a RAM disk big enough for temporary files.
- A ten kilobyte disk cache and a RAM disk big enough for defs and libraries. This configuration is good when the size of temporary files cannot be predicted.
- A disk cache of up to a megabyte and a RAM disk big enough for temporary files, defs, libraries, spool, and sys.

The first configuration is most memory economical. Configurations further down the list use more memory with diminishing returns.

20.9 Repairing Damage

To recover a damaged or deleted file on disk, you must have a way of reading and modifying selected sectors on disk. Several programs are available to do this, including a program from the OS-9 Users Group and a sample Basic program in the Microware Basic Manual.

If a small file has been erased and you catch it before any files are created or extended, you can recover it. The requirement that the file system remain unchanged from the time the file is deleted until the recovery is complete makes this technique unlikely to work on a multi-user system, or even a system with several active processes. If nothing has happened since the file was deleted, you can probably recover it.

This method for recovering a deleted file depends on internal details of RBF. It does not work with versions of RBF before release 2.2, and it is not absolutely guaranteed to work with future versions.

1. First inspect the directory from which the file came. You should find a directory entry that has the file name of the deleted file in it minus the first and last letters. The first letter was changed to a $00 to indicate that the file was deleted. The last letter isn't a standard ASCII character because the high order bit was set on to mark the last byte in the file name.

2. When you have found the right directory entry, change its first byte back to the first character in the file name.

3. Now the file appears in the directory and is readable. Don't write anything on this disk yet! The sectors that made up the deleted file are still marked as free for use. The next file that gets written to the disk may well use an important part of the file you are trying to rescue.

4. Change your default directory to another disk (perhaps a RAM disk) and run ***dcheck –r*** on the disk containing the file you wish to recover. ***Dcheck*** should give error messages about clusters that are allocated to your file but not in the bitmap. Let ***dcheck*** mark the sectors as allocated.

5. If the previous step doesn't work, a file was probably created or extended before you ran ***dcheck***. Give up unless you want to search through all the sectors on your disk pulling out those that contain parts of the file.

6. The disk is now usable.

20.9.1 Recover

The following code recovers a freshly deleted file in the current data directory. It assists with the steps up to 4.

```
#include <stdio.h>
#include <direct.h>
#include <modes.h>
#include <errno.h>
#include <ctype.h>
#include <const.h>

typedef u_char boolean;
```

```
#define FALSE 0
#define TRUE 1

/*
    Prototypes
*/

boolean QRecover(struct dirent *, char *);

main()
{
    path_id dirpath;
    struct dirent Entry;
    u_int32 ct;
    u_int32 location;
    char c;

    stdin->_flag |= _UNBUF;

    if((errno = _os_open(".",
            FAM_DIR |FAM_READ |FAM_WRITE |FAM_NONSHARE,
            &dirpath)) != SUCCESS){
        perror("opening . directory");
        exit(errno);
    }
    ct = sizeof(Entry);
    if((errno = _os_read(dirpath, &Entry, &ct)) != SUCCESS){
        perror("reading . directory");
        exit(errno);
    }

    location = 0;
    while(ct == sizeof(Entry)){
        if(Entry.dir_name[0] == '\0' && (isalnum(Entry.dir_name[1]) ||
                    Entry.dir_name[1] == '.' ||
                    Entry.dir_name[1] == '-' ||
                    Entry.dir_name[1] == '$'))
            if(QRecover(&Entry, &c)){
                if((errno = _os_seek(dirpath, location)) != SUCCESS){
                    perror("seeking in . directory");
                    exit(errno);
                }
                Entry.dir_name[0] = c;

                ct = 1;
                if((errno = _os_write(dirpath, &Entry, &ct)) != SUCCESS){
                    perror("failure re-writing file name");
                    exit(errno);
                }
                (void)_os_seek(dirpath, location);
            }
        ct = sizeof(Entry);
        if((errno = _os_read(dirpath, &Entry, &ct)) != SUCCESS)
            if(errno == E_EOF)
                break;
            else {
                perror("reading directory");
                exit(errno);
            }
        location += sizeof(Entry);
    }
}


boolean QRecover(struct dirent *Entry, char *c)
{

    printf("Erased file name \"?%-.27s\"\n", Entry->dir_name + 1);
    printf("Type <CR> to skip or a valid first character for the recovered file name: ");
    fflush(stdout);
    *c = (char)getchar();
    putchar('\n');
    if(*c == '\n')
        return FALSE;
    return TRUE;
}
```

20.10 Using Brute Force

If the consequences of losing a file are so dreadful that it's worth hours of your time to recover it, you can retrieve the data the hard way. This requires two disk drives and takes a lot of time and effort.

This isn't really a trick. It's just a brute force approach to the problem. In essence we're about to treat the entire disk with the deleted file as a single file that includes all the sectors on the disk. You look through all the sectors selecting ones that look like part of the file you want to recover and build a file including all those sectors. Then, using an editor, you put those sectors into the right order.

It's difficult to recognize a chunk out of the middle of an object module, so this approach is mainly useful when the deleted file contained text. The C program ***scavenge*** (found in section 20.12.3) runs through each sector on the disk named in its command line:

```
$ scavenge /d1@
```

It displays the sector number and the contents of the sector on the screen with the question `Keep this? (yn)`. If you reply, `Y`, it will copy the sector to a file named recover in your data directory. If you reply `N`, the program goes to the next sector.

It is easy to reject the last sector in a file by mistake. The last sector in a file contains the file's last characters, but the rest of the sector is filled with junk. To prevent the junk from deceiving you, keep your eye on the beginning of each sector.

If you are certain you have retrieved all you want of a file before ***scavenge*** has worked through the entire disk, abort the program with a keyboard interrupt. You'll spend long enough running ***scavenge*** without extending the pain!

You won't find a damaged file very often. If you use high-quality diskettes and take good care of them, you may never see a damaged file. The only disks I have had any trouble with are those I received in the mail. The Post Office is the great destroyer of diskettes. Diskettes can only stand so much heat, cold, and folding. Even when a diskette makes it though the Postal filter intact there is a chance for disaster. Your drives may have trouble reading disks created on someone else's drives. Don't give up at the first #244 error. If you can read part of a file, there is a good chance you can get at most of it.

If there is a bad sector somewhere in the file, your best bet is to try to read it several times. If that doesn't work, you'll have to give up on that sector and try to rescue the rest of the file.

20.11 How to Ignore a Bad Sector

You can eliminate a bad sector from a file by fussing with the file descriptor or by copying the file with a program that ignores bad sectors.

The file descriptor describes the location of every sector in a file. A bad sector can be removed from a file by removing the reference to the sector from the file's file descriptor. This leaves the bad sector marked as allocated in the disk's allocation map and prevents another file from using the sector. The segment of the file that contains the bad sector must be split into two sections with neither containing the bad sector.

Editing a file descriptor sounds (and often *is*) complicated. A special copy program that handles bad sectors as it copies the file is less error-prone than editing an FD's segment list. A robust copy program's only major cost is that it has to copy the file; this is a concern with huge files or when there is insufficient disk space for a second copy of the file.

A sample robust copy program, named ***ForceCopy***, can be found in section 20.12.4.

20.12 Programs

Unlike most of the chapters in this book, this chapter uses several programs which generate interesting results but have little educational value in themselves. So instead of interrupting the text, most of the programs for this chapter are collected here.

20.12.1 FDList

The ***fdlist*** program displays the information from a file's FD sector. In particular, it displays a list of the segments allocated for the file.

```
/*
   FDList Usage: fdlist <filename>
*/
#include <stdlib.h>
#include <stdio.h>
#include <direct.h>
#include <sgstat.h>
#include <errno.h>
#include <modes.h>
#include <const.h>

#define SEGSPERLINE                3

static char *ProgName;
struct fdseg {
   u_char addr[3];
   u_char size[2];
};

typedef struct fdseg *SegList;
/*
   Prototypes
*/
static u_int16 GetSectSize(path_id, char *);
static struct fildes * GetFD(path_id, u_int16, char *);
static void OutputFD(struct fildes *, int, u_int32);
static void OutputAttributes(unsigned char);
static void OutputSegList(int, SegList);
```

```
main(argc, argv)
int argc;
char **argv;
{
    register struct fildes * FDPtr;
    path_id FilePath;
    unsigned long FileLength;
    short SectSize;

    ProgName = argv[0];

    if(argc != 2){
        fprintf(stderr, "%s: needs a file name to select an FD\n");
        exit(1);
    }

    /*
        Open for neither read nor write so we cannot be refused access based
        on file protection. The only chance for an access violation is directory
        files. They are handled separately.
    */
    if((errno = _os_open(argv[1], 0, &FilePath)) != SUCCESS)
    /*Handle directory files */
    /*Error != E_FNA means opening with dir-mode won't help */
    if(errno != E_FNA ||
            (errno = _os_open(argv[1], S_IFDIR, &FilePath)) != SUCCESS){
        perror("error opening file");
        exit(errno);
    }

    SectSize = GetSectSize(FilePath, argv[1]);

    FDPtr = GetFD(FilePath, SectSize, argv[1]);


    FileLength = (unsigned char)FDPtr->fd_fsize[3] +
                256 * ((unsigned char)FDPtr->fd_fsize[2] +
                256 * ((unsigned char)FDPtr->fd_fsize[1] +
                256 * (unsigned char)FDPtr->fd_fsize[0]));


    OutputFD(FDPtr, (SectSize -16) / 5, FileLength);

    free(FDPtr);
    _os_close(FilePath);
    exit(0);
}


static u_int16 GetSectSize(path_id FilePath, char *FileName)
{
    struct sgbuf PathOptions;
    u_int32 OptSize = sizeof(PathOptions);

    if(_os_gs_popt(FilePath, &OptSize, &PathOptions) != SUCCESS){
        perror("error getting path options");
        exit(errno);
    }
    return PathOptions.sg_sctsiz;
}


static struct fildes * GetFD(path_id FilePath, u_int16 SectSize, char *FileName)
{
    struct fildes *FDPtr;

    if((FDPtr = malloc(SectSize)) == NULL){
        perror("cannot allocate a sector buffer");
        exit(errno);
    }
    if(_os_gs_fd(FilePath, (u_int32)SectSize, FDPtr) != SUCCESS){
        perror("cannot get FD sector");
        exit(errno);
    }
    return FDPtr;
}


static void OutputFD(struct fildes *FDPtr, int segs, u_int32 FileLength)
{
    char K[16];

    /*Link count is almost always 1, so only output it if it's not 1  */
    if(FDPtr→fd_link != 1)
        printf("Link count: %u\n", (unsigned char)FDPtr→fd_link);

    printf("Owner Grp.User: %d.%d\n", FDPtr→fd_own[0], FDPtr→fd_own[1]);

    if(FileLength >1024)
```

```
        sprintf(K, " (%.2fk)", (double)FileLength/1024.0);
    else
        K[0] = '\0';
    printf("File Size: %u bytes%s\n", FileLength, K);

    OutputAttributes(FDPtr→fd_att);

    printf("Creation Date: %d/%d/%d\n",
            FDPtr→fd_dcr[0],
            FDPtr→fd_dcr[1],
            FDPtr→fd_dcr[2]);

    printf("Last modified: %d/%d/%d %d:%2d\n",
            FDPtr→fd_date[0], FDPtr→fd_date[1],
            FDPtr→fd_date[2], FDPtr→fd_date[3],
            FDPtr→fd_date[4]);

    OutputSegList(segs, (SegList)&(FDPtr→fdseg));
}


static void OutputAttributes(unsigned char Test)
{
    char *bits = "dsewrewr";
    unsigned char mask;

    printf("Attributes: ");
    for(mask = 0x080; *bits; mask >>=1, ++bits)
        if((Test & mask) == 0)
            putchar('-');
        else
            putchar(*bits);
    putchar('\n');
}


static void OutputSegList(int segs, SegList SegPtr)
{
    int segment;
    unsigned short Length;
    unsigned long FirstSector;
    int SegsOnLine;
    char outstr[64];

    for(segment=0; segment <segs; ++segment, ++SegPtr){
        FirstSector = SegPtr→addr[2] +
                256 * (SegPtr→addr[1] +
                256 * SegPtr→addr[0]);

        Length = SegPtr→size[1] +
                256 * SegPtr→size[0];
        if(Length == 0)
            break;

        sprintf(outstr, "(start: $%x, len: %u)",
                FirstSector, Length);

        if(++SegsOnLine == 4){
            SegsOnLine = 0;
            printf("%s\n", outstr);
        }else
            printf("%–25", outstr);
    }
    if(SegsOnLine != 0)
        putchar('\n');

}
```

20.12.2 DiskSpace

```
#include <stdio.h>
/*
    Diskspace
    Pipe the output of
    dir -ear ! grep -v "-eDirectory of" ! grep -v "-e- -" ! grep -v "-et m"
    to this filter. The pipe of grep filters will leave only lines with infor-
    mation about files and blank lines.
    Diskspace ignores two factors that use disk space:
    Format overhead: sector 0, the allocation map, and the root directory,
    Pre-extended files, particularly directories.
    (directories are all at least <segment allocation size> sectors in size.)
*/

#define PROPOSALS           17

struct {
    short SectorSize;
    short ClusterSize;
}Proposal[PROPOSALS] = {
    256, 1, /*Must be here */
    256, 2,
    256, 4,
    256, 8,
    512, 1,
    512, 2,
    512, 4,
    512, 8,
    1024, 1,
    1024, 2,
    1024, 4,
    1024, 8,
    2048, 1,
    2048, 2,
    2048, 4,
    4096, 1,
4096, 2};

unsigned long FileCt = 0;
unsigned long ByteCt = 0;
unsigned long DataSpace[PROPOSALS];
unsigned long FDSpace[PROPOSALS];

/*
    Prototypes
*/
void ParseArgs(int, char **);
unsigned long GetSize(char *);
void AccumulateSize(unsigned long);
void PrintResults(void);

main(int argc, char **argv)
{
    char line[256];
    unsigned long Size;

    stdout->_flag |= _UNBUF;

    ParseArgs(argc, argv);

    Initialize( );

    while(gets(line) != NULL){
        if(*line == '\0') /*a blank line */
            continue;
        Size = GetSize(line);
        AccumulateSize(Size);
        /*
            This program might run for a long time.  Make a reassuring "excla-
            mation point."
        */
        if((FileCt % 50) == 0)
            putchar('.');
    }

    PrintResults( );
    exit(0);
}


void ParseArgs(int argc, char **argv)
{
}


Initialize( )
{
    int i;

    for(i=0; i<PROPOSALS; ++i){
        DataSpace[i] = 0;
        FDSpace[i] = 0;
    }
}


unsigned long GetSize(char *line)
{
    int n;
    short Group, User, Year, Month, Day, Time;
    char Attributes[9];
    char Name[32];
    unsigned long FDSector;
    unsigned long Bytes;

    n = sscanf(line, " %hd.%hd %hd/%hd/%hd %hd %s %lx %ld %s",
            &Group, &User,
            &Year, &Month, &Day,
            &Time, Attributes, &FDSector,
            &Bytes, Name);
    if(n != 10){
        fprintf(stderr,
                "Trouble finding file size.  Only %d fields parsed\n",
                n);
        return 0;
    }
    return Bytes;
}


void AccumulateSize(unsigned long Size)
{
    unsigned long Clusters, Sectors;
    register int i;

    ++FileCt;
    ByteCt += Size;

    for(i=0; i<PROPOSALS; ++i){
        /*At least one full cluster is allocated to the file.   */
        /*Division rounded up  */
        Sectors = (Size + Proposal[i].SectorSize −1)/
                Proposal[i].SectorSize;
        Sectors++;            /*To allow one for the FD  */
        Clusters = (Sectors + Proposal[i].ClusterSize −1) /
                Proposal[i].ClusterSize;
        FDSpace[i] += Proposal[i].SectorSize;
        DataSpace[i] += ((Clusters * Proposal[i].ClusterSize −1) *
                Proposal[i].SectorSize);
    }
}


void PrintResults( )
{
    register int i;

    printf("\nThere are %u bytes of data or directory info on the disk.\n", ByteCt);
    printf("There are %u files and directories on the disk.\n\n", FileCt);

    printf("Sect Sect/ Data FD Overhead\n");
    printf("Size Clus Space Space percent\n");
    for(i=0; i<PROPOSALS; ++i){
        printf("%4d %4d %12.1fk %11.1fk %6.2f\n",
                Proposal[i].SectorSize,
                Proposal[i].ClusterSize,
                (double)DataSpace[i]/1024.0,
                (double)FDSpace[i]/1024.0,
                100.0 * ((double)(DataSpace[i] + FDSpace[i])/
                (double)(DataSpace[0] + FDSpace[0])));
    }
}
```

20.12.3 Scavenge

This version of ***scavenge*** is a crude program. You may want to modify it to suit your needs. For instance, the SECT_SIZE constant might need a different value.

Scavenge works on ordinary files,[4] but only user 0 can use it on a raw device. Raw disks can only be read beyond sector zero by user 0.

```
#include <stdio.h>
#include <direct.h>
#include <modes.h>
#include <errno.h>
#include <ctype.h>
#include <const.h>

#define FALSE           0
#define TRUE            1

#define REC_FILE        "recover"
#define SECT_SIZE       256

typedef u_char boolean;

/*
    Profiles
*/
boolean GetSector(path_id, u_int32, char *);
void DisplaySector(u_int32, char *);
void HexOut(char *);
void CharOut(char *);

main(int argc, char **argv)
{
    path_id diskpath;
    FILE *recover;
```

[4] It's not clear that running ***scavenge*** against an ordinary file would serve any useful purpose.

```
    char sector[SECT_SIZE];
    int This, c;


    stdin->_flag |= _UNBUF;

    if((errno = _os_open(argv[1], FAM_READ, &diskpath)) != SUCCESS){
        perror(argv[1]);
        exit(errno);
    }

    if((recover = fopen(REC_FILE, "w")) == NULL){
        perror(REC_FILE);
        exit(errno);
    }

    for(This = 0 ; GetSector(diskpath, This, sector) ;++This){
        DisplaySector(This, sector);
        (void)printf("\nKeep this? (yn) ");
        fflush(stdout);
        while((c = toupper(getchar())) != 'Y' && c != 'N');
        if(c == 'Y')
            if(fwrite(sector, SECT_SIZE, 1, recover) != 1){
                perror("writing recovery file");
                exit(errno);
            }
    }
    _os_close(diskpath);
    fclose(recover);
    exit(0);
}


boolean GetSector(path_id path, u_int32 sect_number, char *sector)
{
    u_int32 ct;

    if((errno = _os_seek(path, sect_number * SECT_SIZE)) != SUCCESS)
        if(errno == E_EOF)
            return FALSE;
        else{
            fprintf(stderr,
            "Error %d seeking to %d in source disk\n",
            errno, sect_number * SECT_SIZE);
            exit(errno);
        }
    ct = SECT_SIZE;
    if((errno = _os_read(path, sector, &ct)) != SUCCESS)
        if(errno == E_EOF)
            return FALSE;
        else{
            perror("reading source disk");
            exit(errno);
        }

    return TRUE;
}


void DisplaySector(u_int32 sect_number, char *sector)
{
    u_int32 i;
    printf("\n Sector Number: %d\n", sect_number);
    for(i = 0 ; i <SECT_SIZE; i += 16){
        HexOut(sector + i);
        putchar('\t');
        CharOut(sector + i);
        putchar('\n');
    }
}


void HexOut(char *s)
{
    u_int32 i;
    for(i=0;i<16;i += 2)
        printf("%02x%02x ", s[i] & 0x0ff, s[i+1] & 0x0ff);
}


void CharOut(char *s)
{
    int i;
    for(i=0;i<16;++i)
        if(isprint(s[i]))
            putchar(s[i]);
        else
            putchar('.');
}
```

20.12.4 ForceCopy

The following program skips bad sectors while copying a file.

```
#include <stdio.h>
#include <modes.h>
#include <direct.h>
#include <sgstat.h>
#include <sg_codes.h>
#include <errno.h>
#include <const.h>
#define TRUE       1
#define FALSE      0
#define RETRIES   4

typedef enum {Retry, Abort, OK, End}Codes;

/*
    Variables known throughout this file.
*/
static char *InFile = NULL, *OutFile = NULL;
static path_id InPath;
static path_id OutPath;
static int RetryCt=RETRIES;
static int Try=RETRIES;
static unsigned long Location=0;
static struct fildes InFDBuffer;                    /*shared by OpenFiles() and CleanUp() */
/*
    Function Prototypes
*/
void *malloc( );
static Codes Read(path_id, u_char *, int, u_int32 *);
static void ParseArgs(int, char **);
static void OpenFiles(void);
static Seek(path_id, u_int32);
static Codes ForceRead(path_id, u_char *, int, u_int32 *);
static Codes Read(path_id, u_char *, int, u_int32 *);
static Codes Write(path_id, u_char *, int);
static void AnnounceError(u_int32);
void PatchSector(u_char *, int, u_int32 *);
static void CleanUp(void);
static int GetSectorSize(path_id);
static void Usage( );

main(int argc, char **argv)
```

```
{
    int SectorSize;
    unsigned char *buffer;
    u_int32 Length;

    /*
        Prepare
    */
    ParseArgs(argc, argv);
    OpenFiles( );
    SectorSize = GetSectorSize(InPath);
    if((buffer = malloc(SectorSize)) == NULL){
        perror("sector buffer");
        exit(errno);
    }

    /*
        Main loop
    */
    do{         /*Read/Write loop */
        do          /*repeat seek-read several times if required */
            Seek(InPath, Location);
        while(ForceRead(InPath, buffer, SectorSize, &Length) == Retry);

        if(Length >0){          /*If not end of file */
            Location += Length;
            Write(OutPath, buffer, Length);
        }
    }while(Length >0);
}


static void ParseArgs(int argc, char **argv)
{
    register char *ptr;
    if(argc != 3){
        Usage( );
        exit(0);
    }

    /*
        This version of ParseArgs is a bit heavy-weight for what's required here,
        but this makes it easy to add options later.
    */
    for(++argv ; *argv; ++argv){
        ptr = *argv;
        if(*ptr == '-')
            for(++ptr; *ptr; ++ptr)
                switch(*ptr){
                    case '?':
                    default:
                        Usage();
                        exit(0);
                }
        else if(InFile == NULL)                    /* There's no – */
            InFile = ptr;
        else if(OutFile == NULL)
            OutFile = ptr;
        else{
            fprintf(stderr, "Too many file names\n");
            exit(1);
        }
    }
}


static void OpenFiles()
{
    int InSize;

    /*
        Open the input file, create the output file, and give it the input file's
        length.  Don't clone grp.user or protection attributes yet; they might
        prevent this program from writing the file.
    */
    if((errno = _os_open(InFile, 1, &InPath)) != SUCCESS){
        perror(InFile);
        exit(errno);
    }
    if(_os_gs_fd(InPath, 32, &InFDBuffer) != SUCCESS){
        perror(InFile);
        exit(errno);
    }
    InSize = InFDBuffer.fd_fsize[3] + 256 *
                (InFDBuffer.fd_fsize[2] + 256 *
                (InFDBuffer.fd_fsize[1] + 256 * InFDBuffer.fd_fsize[0]));
    if((errno = _os_create(OutFile, FAM_WRITE|FAM_SIZE|FAM_NONSHARE,
            &OutPath, FAP_READ|FAP_WRITE)) != SUCCESS){
        perror("OutFile");
        exit(errno);
    }
}


static Seek(path_id InPath, u_int32 Location)
{
    if((errno = _os_seek(InPath, Location)) != SUCCESS){
        perror(InFile);
        exit(errno);
    }
}


/*
    Read with some error recovery.
*/
static Codes ForceRead(path_id InPath, u_char *buffer,
        int SectorSize, u_int32 *Length)
{
    switch(Read(InPath, buffer, SectorSize, Length)){
        case Retry:
                if(—Try <=0){
                    /*we cannot read this */
                    AnnounceError(Location);
                    PatchSector(buffer, SectorSize, Length);
                    return OK;
                }else{          /*try again */
                    (void)_os_ss_reset(InPath);
                    return Retry;
                }
        case OK:
                Try = RetryCt;
                return OK;
        case End:
                CleanUp( );
                exit(0);
        case Abort:
        default:
                fprintf(stderr, "Error %d on read\n", errno);
                CleanUp( );
                exit(0);
    }
}
```

```
/*
    Read with error detection and analysis
*/
static Codes Read(path_id InPath, u_char *buffer, int SectorSize, u_int32 *Length)
{
    *Length = SectorSize;
    errno = _os_read(InPath, buffer, Length);
    if(errno != SUCCESS)
        switch(errno){
            case E_EOF:
                    *Length = 0;
                    return End;
                    break;
            case E_SECT:
            case E_CRC:
            case E_READ:
            case E_NOTRDY:
            case E_SEEK:
                    *Length = 0;
                    return Retry;
                    break;
            default:
                    *Length = 0;
                    return Abort;
        }
    else if(*Length == 0)
        return End;
    else
        return OK;
}


/*
    write() enhanced with error detection and quit in case of an error.
*/
static Codes Write(path_id OutPath, u_char *buffer, int SectorSize)
{
    u_int32 Length=SectorSize;
    if(_os_write(OutPath, buffer, &Length) != SUCCESS){
        perror(OutFile);
        exit(errno);
    }else
        return OK;
}
```

```
static void AnnounceError(u_int32 Location)
{
    fprintf(stderr, "Patching bad sector at %u in %s\n",
            Location, InFile);
}


/*
    Copy the last byte of the last sector successfully read throughout this
    buffer.
*/

void PatchSector(u_char *buffer, int SectorSize, u_int32 *Length)
{
    register char c;
    register int i;

    c = buffer[SectorSize −1];
    for(i = SectorSize; i >0; ––i)
        *buffer++ = c;
    *Length = SectorSize;
}


/*
    Set the grp.user, last modified date, and protection attributes of the
    output file the the same values as the input file. Then close the files.
*/
static void CleanUp( )
{
    if((errno = _os_ss_fd(OutPath, &InFDBuffer)) != SUCCESS){
        perror("error writing fd");
        exit(errno);
    }

    if((errno = _os_ss_attr(OutPath, InFDBuffer.fd_att)) != SUCCESS){
        perror("setting permissions");
        exit(errno);
    }
    (void)_os_close(InPath);
    (void)_os_close(OutPath);
}


static int GetSectorSize(path_id InPath)
{
    struct sgbuf buffer;
    u_int32 size=sizeof(buffer);

    if((errno = _os_gs_popt(InPath, &size, &buffer)) != SUCCESS){
        perror(InFile);
        exit(errno);
    }
    return buffer.sg_ssize;
}


static void Usage( )
{
    static char *Message[ ] = {
        "forcecopy",
        "usage: forcecopy [-?] <from_file> <to_file>",
        "\t-?\tdeliver this message",
        NULL
    };
    register char **ptr;

    for(ptr=Message; *ptr; ++ptr)
        fprintf(stderr, "%s\n", *ptr);
}
```

Chapter 21

Performance

This chapter is based on a large bulk of performance measurement done at Microware as part of the OS-9 3.0 project. That research, and this chapter, focus on the system services that are likely to be used by real-time code. This chapter summarizes some of the measurements and discusses the use of the information.

Performance information is important to real time programmers, but it should be used carefully. Performance depends on many things, some of them quite subtle. With the figures presented in this chapter you can make predictions that should approximate reality on your target system. On hardware similar to the Motorola VME boards used to run the tests it should be impossible to get worse performance than the low-level timings. Changing the hardware configuration or even the placement of code and data in memory can change performance. The entire system influences performance. A slow processor will lead to slow execution, so will off-board RAM, slow bus interfaces, DMA activity, and placement of code and data that works poorly with the cache. The arcane art of controlling the contents of the cache can make at least a factor of two performance difference on the 68040.

21.1 Think Like an Engineer

An engineer would not design a bridge barely strong enough to bear the expected load. Good engineering practice would include calculating the maximum possible (not just the expected) load and designing the bridge to hold at least twice that much. Software designers are seldom allowed to operate that cautiously, but it is good to consider the engineering mindset.

Anyone designing a substantial real-time system should invest some effort in timing analysis. Simple performance predictions are useful from preliminary study through final debugging. Early in the design process crude performance analysis can help decide whether an idea is practical. Later, predicted performance can be compared with experimental measurements. Experimental data that disagrees with predicted figures may point out a defect in the implementation, or it might be a sign of flawed analysis. In either case the information is useful.

It is possible, though not easy, to characterize simple problems on simple microprocessors. For such situations perhaps large safety margins are hard to justify. If all the input and output for a system can be placed at precise times, and the execution time of the algorithms used to process each event do not depend on their inputs, the system is "easy to characterize." If the problem can be solved with a processor less complex than the 68020 the execution time can be calculated.[1]

With more "advanced" processors than the 68020, calculation of the execution time for a code fragment, or even a single instruction, becomes difficult. Memory characteristics, pipelining, and caching combine with interrupts to complicate calculation of execution time. As the pipelines and caches grow, the complexity increases. The execution time of a code fragment on the 68040 can vary by a factor of two or more depending on alignment, the state of the cache, and the state of the instruction pipeline. Interrupt processing may completely disrupt the cache, or it may have little effect.

If precise timing predictions are important, use the simplest hardware you can find. Use static RAM with no wait states, avoid processors with an SSM, and don't use a cache unless you can control the contents of the cache. Even with apparently simple hardware, I would not trust a prediction until it was tested on the target hardware.

21.2 Classes of SVC

The fine details presented in an analysis of system call performance is a little misleading. Subtle hardware changes can change performance enough to make a claim of even two significant figures over optimistic. Especially on the higher-end processors, it's better to think of timing information with a course grain. The OS-9 SVCs can be divided into four classes: very fast, fast, medium and slow.

Most of the very fast calls are strictly informational, or they change system global or process descriptor variables. The class includes FID, FSetSys, F$SigMask, and a number of others.

Some of the fast SVCs are powerful. The class of fast, powerful system calls includes all the IPC functions supported by the kernel. Most of the fast SVCs take about twice as long as the very fast functions.

[1] CPUs less sophisticated than the 68020 core have tractable performance characteristics. The manual lists the number of clock cycles for each instruction and each addressing mode.

In the set of interprocess communication SVCs, semaphores are faster than events even ignoring the exceptional no-contention performance of semaphores, when they are used on the atomic kernel. On the full kernel with an SSM in place events are faster than semaphores. Events are usually a little faster than signals. See figure 21.4.

The medium-speed SVCs include most of the resource-allocation functions: memory allocation, module link/unlink, and event and alarm creation and deletion. Real-time code should be designed so the medium-speed SVCs are called before or after real-time activity.

The performance of the slow SVCs is hard to characterize. They are much slower than the other system calls in typical applications. They also have unusually complex performance characteristics. The best advice is to execute these SVCs before or after doing real-time computations. Some slow SVCs are F$Fork, F$Chain, some debugging SVCs, event creation when the event table is expanded, F$Exit, I$Create, and I$Delete.

21.3 Interrupts

Interrupt service and associated activities are at the core of real-time programming. Interrupt service includes these five phases:

Interrupt latency Time before the CPU recognizes an interrupt.

Interrupt service If the interrupt service routine can handle the interrupt without the help of a process, this is followed by a brief epilog and interrupt service is over. If the interrupt service must activate a process the phases continue

Process Activation The interrupt service routine activates a process.

Interrupt Epilog the housekeeping involved in context switching.

Preemption delay any time added to the interrupt epilog while another process gets to a point where it will allow preemption.

These phases can be represented in the above sequence on a time line, see figure 21.2.

21.3.1 An Analogy

The time line for human interrupt handling is similar to OS-9's time line. Imagine driving down a country road. One foot is on the accelerator, the other is tucked comfortably into the corner. At this precise instant you are looking at the radio dial. A cat runs into the road a short distance ahead. After a moment your eyes leave the radio and return to the road. Now you see the cat. You quickly stop thinking about

Table 21.1: Classified System Calls

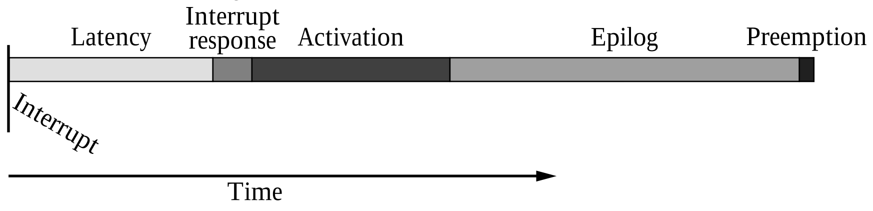
Very Fast	Fast	Medium	Slow	Complex	Unrated
F$CCtl	Ev$Wait	A$Delete	F$Chain	F$AllBit	F$DExec
Ev$UnLnk	Ev$WaitR	A$Set	F$DExit	F$CmpNam	F$Load
Ev$Read	F$Sleep	A$Cycle	F$DFork	F$CpyMem	F$PErr
Ev$Info	F$SPrior	A$AtDate	F$Exit	F$CRC	F$STime
Ev$Pulse	F$Send	A$AtJul	F$Fork	F$DatMod	F$SysDbg
Ev$Signl		Ev$Link		F$DelBit	F$UAcct
Ev$Set		Ev$Creat		F$GBlkMp	
Ev$SetR		Ev$Delet		F$GModDr	
F$Gregor		F$SRqCMem		F$GPrDBT	
F$ID		F$SRqMem		F$GPrDsc	
F$Icpt		F$SRrMem		F$Link	
F$Julian		F$UnLink		F$PrsNam	
F$RTE		F$UnLoad		F$SchBit	
F$Sema		F$Wait		F$SetCRC	
F$SetSys					
F$SigMask					
F$SigReset					
F$STrap					
F$SUser					
F$Time					
F$TLink					
F$Trans					

At best the execution time of complex system calls may be comparable with fast system calls, but they depend on one or more variables. Even typical use may be medium performance or worse.
The execution time of unrated system calls is hard to predict.

Table 21.2: System Call Timing By Class

Class	68070	68000/010	68020	68030	68040
	9.8 Mhz	10Mhz	16Mhz	25Mhz	25Mhz
Very fast	200 µs	150 µs	60 µs	50 µs	20 µs
Fast	400 µs	250 µs	100 µs	60 µs	30 µs
Medium	5 ms	2 ms	0.5 ms	300 µs	100 µs
Slow	15 ms	10 ms	4 ms	3 ms	1 ms

Figure 21.1: Interrupt Service Time Line



the radio and start making a plan to avoid the cat. You take your foot off the gas and move it to the brake, then apply the brake and steer to avoid the cat. With the event over, you return to your previous train of thought.

For the first second or two you were not even looking at the road so you were not able to perceive the cat. In computer terms your video interrupt was masked. If I wanted to determine the cat's chances in advance, I'd want to know the longest time you could look away from the road; that is, I'd like to know your maximum video interrupt latency.

After you looked at the road, you saw the cat and started making a plan of action. The interval between the time your eyes detected the cat and the time your brain started working on the problem was short, but in this time your brain changed from one topic to another. A well-disciplined mind might have saved enough context to be able to return to the original train of thought after the cat event was over. This sudden change from peaceful thinking to event processing is interrupt service.

The interrupt service code in the brain activated at least two or three processes. One process removed the right foot from the accelerator pedal and placed it on the brake pedal. Another process operated the steering wheel. On a car with a manual transmission, a third process moved the left foot to the the clutch pedal. The is the process activation stage of interrupt service. Some action might be taken on reflex. Simple, reflex activities like jerking your hand off a hot surface need to be as fast as possible, so they are programmed into the spinal cord. This is equivalent to building the response code right into the interrupt service routine.

The brain may have reacted to seeing the cat by activating many trains of thought to find ways to deal with it. Since the brain is a parallel architecture, it could start all the trains of thought quickly and run them concurrently until it found a few that seemed worth trying. An OS-9 machine is not so lucky. It must activate the processes serially, then wait until the interrupt service code completes before it even starts to execute the processes. On OS-9, process activation is the time it takes the system to activate a waiting process when it is called from an interrupt service routine. The interrupt epilog is the time it takes to switch from the interrupt service code to the newly activated process.

Figure 21.2: Estimated Interrupt Performance

CPU	Latency (µs)	IRQ (µs)	FIRQ (µs)	Activation (µs)	Epilog (µs)
68070 (9.8 Mhz)	233	45	36	228	403
68000 (8 Mhz)	207	40	32	203	358
68010 (12 Mhz)	135	26	21	132	233
68020 (16 Mhz)	70	13.4	10.6	68	120
68030 (25 Mhz)	55	12	10	48	84
68040 (25 Mhz)	31	7.5	7	22	28

Times for the 68020 and 68040 are measured. Others are estimated.

Even if the cat is recognized in what should be plenty of time, it is not necessarily safe. A driver who turns on the cruise control and sticks both feet out the window increases the preemption delay greatly. Even after the cat is seen and the interrupt service routine schedules the feet for some activity—brakes…hard—the feet don't respond. They are busy trying to untangle themselves from the window opening. This is equivalent to preemption delay. Preemption delay is the interval when the kernel knows it should run a different process, but it cannot because the current process has disabled preemption. As soon as preemption is reenabled, the kernel switches to the new higher-priority process.

21.3.2 Data

Figure 21.2 gives approximate values for the time spent in each phase of interrupt service. Table 21.8 lists the performance costs of software "options." Hardware also plays an important role. Interrupt service, especially the interrupt response interval is very sensitive to memory performance. The performance of the Motorola processor boards used to make the measurements are not exceptional in either direction, but it is probably fair to guess that unless you know you have a high-performance system you will probably not get better worst case numbers than are given here.[2]

Figure 21.2 includes timing data for each phase of the interrupt response time line. The environment for these measurements was contrived to try to generate the worst possible times. The time line including the predicted times for all the phases of interrupt service on a 25 Mhz 68040 is 74 microseconds long.

Table 21.3 presents a high-level measure of interrupt service that seems to conflict seriously with the data from figure 21.2. It claims that the same 68040 used to measure

[2] Worst case is hard to define in a complex system. Here it means that the cache contained no useful data and the interrupt was taken from the master stack. Measurements varied by less than ten percent and the given numbers are the worst measurements encountered.

Measurements were made on a MVME167 for the 68040 and an MVME133 for the 68020. The table shows estimated values for other processors.

Table 21.3: Estimated Maximum Interrupt/Signal Rates (Atomic Kernel)

System	CPU	Clock Rate						
		8	12	16	20	25	33	40
MVME117	68010	2100	3200	4200	5200	6500	8600	10400
MVME133-1	68020	2800	4300	5500	6900	8700	11400	13800
MVME147SA-1	68030	2200	3300	4300	5400	6800	9000	11000
MVME167	68040	8600	13500	17300	21600	27000	35600	43200

the intervals used for the time line can:

- Service an interrupt
- Send a signal
- Receive the signal with a signal intercept routine
- Return to the kernel to get another signal

all in about 40 microseconds. Apparently OS-9 can do everything in the interrupt time line plus an F$RTE system call all in a little more than half the time the time line says it takes for just an interrupt.[3]

There are several reasons for this discrepancy:

1. The high-level benchmark has only one process. That process is always busy intercepting signals as fast as it can. This shortens the epilog greatly.
2. The time line in figure 21.2 represents worst-case timing. The high-level benchmark is ordinary, rather simple, code. It does not attempt to generate worst-case performance.
3. Because of its simple design, the high-level benchmark does not experience either interrupt latency or preemption delay.

Taking these factors into account, interrupt service time should be less than half what the time line suggests. The code executed in the interrupt service routine and the F$RTE system call made each time the signal intercept routine executes account for the remaining time.

21.4 Interrupt Latency

[3] The epilog is longer when the target process is activated with a normal signal instead of a wakeup signal, an event, or a semaphore.

Table 21.4: System Calls That Mask Interrupts

System Call	Remarks
F$Alarm	Masks while maintaining the list of alarms.
F$AllPD	Masks interrupts briefly except when it needs to expand the process table (not applicable on the Atomic kernel.) It also uses F$SRqMem which masks interrupts.
F$AProc	Masks interrupts for about 70% of the system call.
F$Chain	Masks interrupts while activating the new process and starting the next process. These are done separately with interrupts unmasked between them.
F$Event	Masks through the context switching calls. It also masks interrupts when the event table is expanded (not applicable on the Atomic kernel.)
F$Exit	Calls F$RetPD and F$SRtMem which mask interrupts.
F$FIRQ	Mask interrupts for about 20 instructions.
F$Fork	Masks interrupts while creating the process descriptor, allocating memory and while putting the new process in the active queue.
F$IRQ	Mask interrupts for about 20 instructions.
F$NProc	Mask interrupts for about 20 instructions.
F$Sema	Masks interrupts for about 70% of the system call.
F$Send	Masks interrupts for about 70% of the system call.
F$Sleep	Masks interrupts for about 70% of the system call.
F$RetPD	Uses F$SRtMem to return memory.
F$RTE	Masks interrupts for about 60% of the system call. This becomes significant when F$RTE shrinks a signal queue. In that case it uses F$SRtMem.
F$SRtMem	Masks interrupts for about 90% of the system call.
F$SRqCMem	Masks interrupts for about 90% of the system call.
F$SRqMem	Masks interrupts for about 90% of the system call.
F$Time	Masks interrupts briefly.
F$Wait	Masks interrupts for a large part of the system call.

21.5 Estimating

An early step in the design of the real-time control system for a new ultra-fast doughnut maker is estimation. The designer needs to discover whether the problem left to the software can be solved at all, if it can be handled with resources that are within some stretch of the budget, and if enough slack can be left in the design to permit a high-level implementation.

21.5.1 Impossibility

The check for simple impossibility may be quick, but it is not easy. The problem is that most calculation can only show the impossibility of an implementation strategy. It is hard to show that no strategy can succeed. If the jelly injector component of the doughnut maker must be serviced 50,000 times per second it cannot use an interrupt- and signal-based implementation even with a 40 Mhz 68040. Since that processor cannot service interrupts and send signals to a user process faster than about 43 thousand interrupts per second, we can rule out a two-level interrupt-driven design.

All we can easily rule out is a largely user-state implementation. The overhead for a simple interrupt service routine is about 10 microseconds. If it takes more than 10 microseconds per iteration to service the injector, a 40 Mhz 68040 is barely fast enough to handle 50-thousand events per second, but it might be possible to squeeze a little more performance out of a system. The cache will probably have a strong effect on a tight loop including the kernel interrupt service code and a short interrupt service routine. The cache might boost performance enough to give an interrupt service solution a little extra speed. A real optimist might even hope to handle eighty-thousand events per second.

If no context switch is involved the kernel adds about 5 microseconds of overhead before and 6 microseconds after the interrupt service routine on a 40 Mhz 68040. Even if the service code takes 15 microseconds (for a total of 26 microseconds per interrupt) it does not rule out a solution. It rules out an entirely interrupt-driven solution, but a polling loop is still a viable approach. A polling loop would add a little overhead to the service time for each event. If it adds an entire microsecond (unlikely), a polling loop can handle about 66000 events per second.

Given that service for each event requires a non-reducible 15 microseconds on a 40 Mhz 68040 and that the interrupt rate is fifty-thousand per second, we can call the problem practically intractable if the fastest available processor is a 25 Mhz 68040. That means that either we need a faster processor or a simpler design.

Let's assume that the budget does not support a 68040-based solution, and has to be completed on a reduced budget. The jelly injector is permitted its own processor, but only a 16 Mhz 68020. We are also given a lower expected load, only 4000 events

Table 21.5: Interrupt Performance of 68020

Interrupt response (IRQ)	13.4 µs
Interrupt response (FIRQ)	10.6 µs
Return from interrupt	16 µs
Interrupt/Signal pairs per second	5500

Table 21.6: Calculated Values for a 16MHz 68020

Maximum event rate in a polling loop	10000/sec
Time for event service plus interrupt overhead	130 µs
Maximum interrupt rate	7692/sec
Maximum rate with one signal per interrupt (no application code)	5500/sec
Minimum time for interrupt plus signal	182 µs
Expected time	225 µs
Expected time for event service plus interrupt and signal overhead	325 µs
Expected service rate	3077/sec

per second.

The interrupt performance parameters for a 16 Mhz 68020 processor are summarized in table 21.5.

If the application needs 100 microseconds to service each event $t_e = 100$ and $\text{EventRate} = 1/t_e = 10000$ events/s.

If interrupt response time is included as part of the cost of servicing each event, t_e, becomes 1030 µs and *EventRate* becomes 7692 per second.

The inverse of the number of interrupt/signal pairs the system can handle per second is $1/5500 = 182ms$. This is an optimistic estimate of the time to handle an interrupt and send a signal. If we add 25% to the optimistic time to get a more realistic estimate we get $t_{si} = 225ms$.

Adding t_e to t_{si} gives 325 µs per interrupt or 3077 events per second if much of the processing for each event is performed in in user state.

The results of these calculations are summarized in table 21.6. These values indicate that a 16 Mhz 68020 can handle event rates between 3000 and 10000 per second depending on the way the code is implemented. Our requirement is 4000 events per second, so we can say that the system has at least the aggregate capacity to handle the load.

More specifications are required before we can determine whether the system can meet deadlines. All we have calculated is that in a second the system can handle the work that arrives in an average second.

21.5.2 Possibility

Since the problem appears tractable, it's worth looking at it more carefully. Events do not arrive at regular 250 microsecond intervals. They arrive in bursts of 200 events spread uniformly over two millisecond intervals. The peak rate is 4000 per second, so in a second the system must handle at most 20 bursts of 200 events. There is never less than 35 milliseconds of dead time between bursts.

Events arrive every 10 microseconds during a burst. The interval between events is too short to support even interrupt processing overhead, much less communication with a process or event processing code. We can only handle this event rate if we execute only a small fraction of the event handling code when the event occurs. An implementation must divide the event handling code into a part that must be executed within ten microseconds and another part than can wait at least two milliseconds. For the jelly injector, two microseconds of code must be executed immediately (within 10 microseconds) after each event, the remaining 98 microseconds may be executed up to 3 milliseconds later.

The jelly injector collects some redundant data. It can lose a few interrupts without serious difficulty, but if more than two consecutive interrupts are lost or more than 2% of interrupts are lost over a burst the machine will turn out inferior doughnuts. After the burst, the interrupt service routine can either handle the second part of the processing for each event or it can send a signal to a process that will handle the processing.

A summary of the estimated time line for an event burst is shown in figure 21.3. It shows that the data associated with the first event in a burst will be lost, but that all other events in each burst will be captured and processed without difficulty.

The time line in figure 21.3 ignores interrupt latency. The first event in the burst will always be lost, but this is tolerable. If the background load on the system is not controlled, interrupt latency could make the delay in entry to the interrupt service routine much worse than the interrupt response time. If the interrupt latency is greater than nine microseconds the second event in the burst will be lost as well as the first. A latency of nine microseconds will shift the time line so processing for the second event does not start until the third event occurs.

Interrupt latency is caused by five factors: hardware overhead, instruction completion, interrupt masking outside the kernel, interrupt masking in the real-time subset, and interrupt masking outside the real-time subset.

Hardware overhead Assume that the low-level interrupt dialog takes a few tenths of a microsecond, an insignificant interval. This is a characteristic of the CPU and the hardware between the CPU and the I/O device.[4]

[4] Hardware overhead is not always insignificant. Sometimes it can be several microseconds.

Figure 21.3: Time Line for System State Implementation

Time	Action
0	First event
10	Second event. First event is lost
11	Interrupt response time over. Execution is in the interrupt service routine
13	Preliminary processing for second event done.
13	Start polling for third event.
20	Third event arrives.
22	Preliminary processing for third event done.
22	Start polling for fourth event
30	Fourth event arrives.
32	Preliminary processing for third event done.
	Polling loop continues until it has handled 200 events.
1992	Preliminary processing for 200th event done.
1992	Start secondary processing of first event
2090	Secondary processing of first event done.
21592	Secondary processing for last event done.
	Exit interrupt service routine
21608	Resume interrupted activity
35000	The next interrupt arrives

Instruction completion Interrupts are not handled until the end of the current instruction. On the 68020, no instruction uses more than about 200 clock cycles. This means that the longest an interrupt will be delayed for completion of the current instruction is about 200 clock cycles, or about 13 microseconds on our 16Mhz 68020. This instruction latency can be long enough to cause the system to drop an additional event if the processor is executing a particularly complex instruction.[5]

Interrupt masking outside the kernel Device drivers frequently mask interrupts to the level of their device, but that problem can be controlled by:

- Minimizing periods with interrupts masked.
- Giving a device with critical timing constraints a high interrupt priority. In this case we might use an interrupt priority of five for the injector and assign lower priorities to all other interrupt sources.

Interrupt masking in the real-time subset Unless the load on the OS is severely restricted, maximum interrupt latency can easily rise to about 60 microseconds. If a non-real time load is running, the system may experience latency up to about 200 microseconds. We can either accept the possibility of lost events, avoid division, use a faster processor, or use input hardware that maintains a short queue of events.

If the system will include user-state background processing, that code must not use dangerous system calls (see table 21.4) during real-time periods. Even a simple context switch could cause an excessive delay in processing the first interrupt in the burst. Some easy ways to prevent inconvenient context switching are:

1. Have no active processes. When no processes are active the kernel executes a `stop` instruction that waits for any interrupt. This gives very fast interrupt response.
2. Have only one active process. If there are no processes in the active queue, the kernel does not even attempt to context switch at timeslicing intervals.
3. Turn off the system ticker. This makes timeslicing intervals infinitely long. It also disables timed sleeps and alarms, and may cause difficulties with some device drivers and file managers.
4. Ensure that there is no more than one active process when an event interrupt arrives. At other times any number of processes may be active.

[5]Division with indexed memory indirect addressing mode needs about 200 clock cycles. Most instructions need less than 12 clock cycles.

Interrupt masking outside the real-time subset It's also important to avoid system calls that mask interrupts extensively. System calls that allocate or free memory are especially troublesome.

To be safe we must ensure that the system is idle when it takes each interrupt. Any other activity risks losing more than one event per burst.

If it is not too late to get hardware changes we should consider a FIFO for input events. A 32-entry-deep FIFO would handle nearly any combination of interrupt masking intervals and would deliver the data with no loss of events. The 32 entries would give the interrupt service code about 330 microseconds between the time the interrupt for the first event in the service is sent and the time the first event is lost. This is enough time to cover most problems.

A schedule that allocates about 60% of CPU time is reasonable. Even at 80% utilization an OS-9 system can can handle anything but very hard real time without cycle-by-cycle analysis. It's not foolish to have unused CPU cycles. A good margin lets us ignore less significant factors. We are ignoring issues like the influence of DRAM refresh, DMA, and contention from other processors. In a perfect world, it is good to have at least double the amount of CPU time required. Unexpected requirements and issues will arise after the hardware is frozen, and a system that is pushed to its limits tends to be unforgiving of any problem.

21.5.3 Move to User State

User state code is much easier to debug than an interrupt service routine. If possible, all processing that is not directly associated with the interrupt or some other aspect of the hardware should be done in a process. If we use an event to control the process, we can activate the process by signalling the event from the interrupt service routine after the interrupt service routine completes preliminary processing for the 200th event. The time line looks like this:

Time	Duration	Action
0	11µs	First event. Execute FIRQ interrupt response code
10		Second event. First event is lost
11		Interrupt response time over. Execution is in the interrupt service routine.
13	2µs	Preliminary processing for second event done.
13		Start polling for third event.
20		Third event arrives.
22	2µs	Preliminary processing for third event done.
22		Start polling for fourth event
30		Fourth event arrives.
32	2µs	Preliminary processing for third event done.
		Polling loop continues until it has handled 200 events.
1992		Preliminary processing for 200th event done.
1992	60µs	Signal the event
2052	120µs	Return from the interrupt service routine. Run interrupt epilog.
2172	19600µs	Start execution of the process.
21772	100µs	Execute `Ev$Wait` system call
21872		Process is waiting in event queue.
35000		Next interrupt arrives

For this system, moving to user state adds only about 270 microseconds to the schedule for each burst. It is worth serious consideration.

21.5.4 And It All Means

This quick analysis shows that interrupt latency is the major pitfall waiting for the jelly injector. Interrupt response time is too slow to support completely interrupt-driven code, but a polling loop is more than fast enough. Given the structure that falls out of the analysis, the cost of moving most of the processing load to user state is insignificant. Everything looks good except the possibility of uncontrolled interrupt latency.

If the system is designed so the processor is stopped whenever it is expecting an interrupt, the code will be safe. Problems may, however, arise sometime in the future when the system is modified without respecting that rather odd constraint. If the hardware could buffer 16 events it would let the system tolerate well over 100 microseconds of interrupt latency without losing any events. Hardware could also help by giving us a priming interrupt. If it could anticipate the first event by about 200 microseconds and raise an interrupt to alert the software, the polling loop would start in time to catch the first event in a burst even with system calls outside the real-time subset on an atomic kernel with the buddy system allocator. The development kernel can still lose events if the warning arrives during an extensive table resize operation.

If we can't get hardware help, we could consider using the system ticker. We know that we can safely spend a full millisecond running other code after the system finishes processing a burst of data. We will call for a time-driven interrupt one millisecond after the user state code finishes handling a burst of events. The event will always arrive in time to get the polling loop started well before data arrives.

21.6 Some Derived Numbers

The graphs in this section attempt to condense some data and use it to draw conclusions.

Figure 21.4 compares the speed of several synchronization mechanisms on various processors. Pipes are used for synchronization by reading a single byte to block and writing a byte to unblock the waiting process. Signals are intercepted, and they are sent slowly enough that the blocking process executes an `F$RTE` and `F$Sleep` for each signal. Wakeup signals only involve an `F$Send` and an `F$Sleep` per IPC. Synchronization with events uses Ev$Signl and Ev$Wait. The time to execute semaphores counts both the library routine and the supporting kernel code. Fast semaphore performance is measured by a single process that P()'s and V()'s a semaphore repeatedly. The semaphore operations never need to call the kernel.

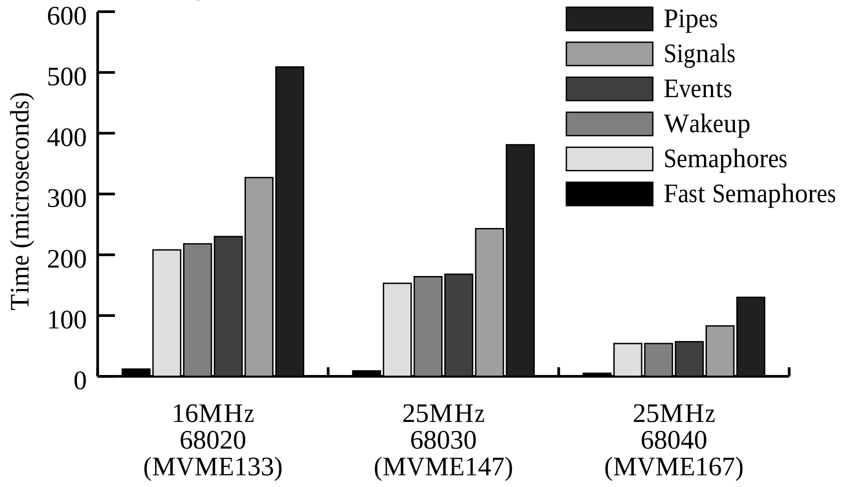
Figure 21.4 shows that fast semaphores are much faster than any other inter-process communication mechanism. Beyond that there's not a lot of difference between events, wakeup signals, and slow semaphores. Since wakeup signals are not generally suggested for user-state processes and events are more convenient than semaphores, this graph shows that when contention is expected events are generally the best choice.

Intercepted signals and pipes are special mechanisms with powerful features beyond simple synchronization. The graph shows that they should not be used when one of the other mechanisms will suffice.

Figure 21.5 compares a composite kernel-performance rating for five platforms. Since they are based on a set of kernel performance numbers these ratings should predict worst-case kernel performance better than benchmarks such as Dhrystone or Specmark. The benchmarks that make up the composite number are the same performance figures used throughout this chapter. IPC and other real-time functions are weighted heavily and memory allocation and other non-realtime functions are weighted lightly. This shows the effect on OS performance of the architectural evolution of the 68000 line.[6]

[6] The 68070 is not strictly a member of the 68000 family since it is made by Signetics instead of Motorola. Although the figures show that it is the slowest processor that executes the OS-9 kernel, it is not the first member of the family. The 68070 is an early highly-integrated 68000-clone that is used in many CD-I players.

Figure 21.4: Execution Time of IPC Functions



The kernel benchmarks show that kernel code (and other similar code) has performance characteristics unlike general user-state code. Motorola's performance ratings for the processors (running in optimum systems) would suggest that the 68030 should rate about five and the 68040 should rate about sixteen. The discrepancy between Motorola's predictions and the kernel measurements is partly explained by the fact that Motorola doubtless expects the processors to take full advantage of their caches while most of the kernel benchmarks take care to flush the instruction cache before each system call. The detailed benchmark numbers also show that the particular type of MVME147 used for the benchmarking has slow memory compared with the other processors. When use of the cache is minimized, slow memory becomes important. Finally kernel code is primarily logic, bulk memory access, and address manipulation with little character manipulation, arithmetic, or looping.

Although only the MVME133 actually used a 16 MHz CPU clock, all systems are normalized to that rate. This is supposed to make it easier to compare the system architectures. Many processors actually include 16 Mhz in their range, but any clock rate would have sufficed. The approximate effect of clock rate on performance is easy to calculate. The effect of changing to a different processor is hard to estimate.

I have a little trouble believing the performance measured for the 68030. The most likely explanation is that the system used to measure the numbers, an MVME147SA-1, is relatively low-performance. It certainly demonstrates that the CPU type and clock rate is not enough to predict system performance accurately.

Figure 21.5: Average Kernel Speed Factor—All Processors at 16 Mhz

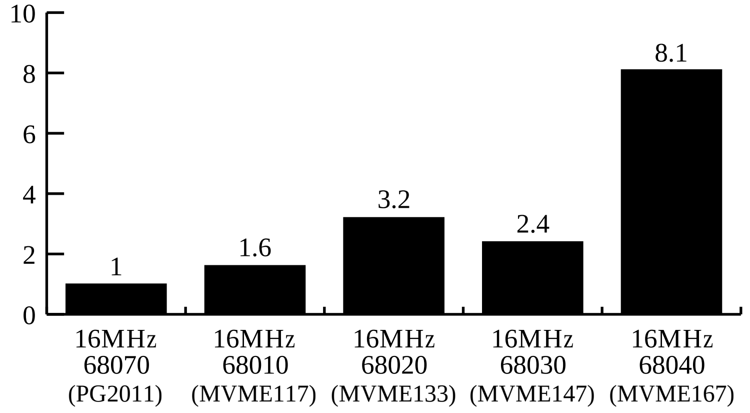


Table 21.7: Motorola MIPS Ratings

	Frequency MHz								
Part	8	10	12	16	20	25	33	40	50
68000	.8	1	1.2	1.6					
68020				2.6	3.5	4.4	5.5		
68030				4	5	6.1	8	10	12.1
68040						22	29	35	

21.6.1 Other Processors

System service times measured on the 68020 can be used to estimate times for other processors. Figure 21.2 uses 68020 and 68040 times and performance ratios derived from a number of benchmarks to predict interrupt service times for various processors.

No measurements are given for the 68000 or for any processor in the 683XX family, but information for these processors can be inferred. The kernel is not optimized for the 68010, so the 68000 should perform approximately like the 68010. The processors in the 683XX family reuse CPU cores[7] from other 68XXX-family processors, but use a 16-bit bus interface. Since the kernel does not use bitmap instructions or indirect addressing modes, the CPU32 should perform roughly like the 68020 except for operations that feature data movement. Other 683XX processors should perform like the 68000 or the 68030.

21.6.2 SSM and FPU

The MMU and FPU can seriously hurt kernel performance. An MMU may impose a performance penalty in three places:

1. When a process' memory map is changed, the memory map for that process must be changed. This can roughly double the cost of memory allocation and deallocation.

2. There is always a penalty for TLB misses, and the 68020/68852 adds a wait state to every memory reference.

3. Every context switch includes a call to the SSM module to switch memory maps.

When it is in use, the FPU adds about 40% to the interrupt epilog component of context switching time time. If the process that was running dirtied the FPU (by changing its state since the process was activated), the kernel saves its FPU state. If the next current process has a saved FPU context, additional time is spent reloading the process' context. The kernel checks for FPU activity before it saves the FPU state, consequently having an FPU in the system and not using it does little harm to the kernel's performance. The kernel must check the FPU's dirty bit on context switches to determine whether an FPU save is required, but that operation is fast compared to the FPU save.

[7] The CPU components of the 683XX line are similar to earlier processors in the 68000 line, but they are not identical. Even instructions that appear identical often have different timings.

Table 21.8: Extra Interrupt Service Costs

Option	Interval	68020	68040
Use trap call for activation	Activation	36 µs	10 µs
FPU Context switch (requires 2 FPU processes)	Epilog	48 µs	8 µs
FPU Context save (only interrupted process uses FPU)	Epilog	25 µs	3µs
Use a non-wakeup signal for activation	Epilog	23 µs	8 µs
Use SSM	Epilog	36 µs	3 µs

Chapter 22

Security

The security of an OS-9 system depends on how it is configured and administered. This chapter discusses OS-9's security features, the related configuration options, and security issues in system administration.

Unix system administrators worry about the "wily hacker." DOS users are infested with countless viruses. Trojan horses, worms, salami fraud, and other pitfalls and vile practices abound. Thus far OS-9 has not been attacked. Perhaps the OS-9 universe is too small a target to rate such attention, or maybe it's too difficult to crack. The truth is probably a combination of those factors and the peculiarly high integrity of OS-9 wizards.

About five years ago OS-9 went through a period of recreational attack. A number of students at universities in United States and Europe looked for ways to "crack" OS-9.[1] This wasn't a malicious game; they were using multi-user OS-9 systems for class work and had no reason to want to break their tools. It was an informal contest between OS-9's maintenance team and the students. I was in the middle—more or less the referee.

This contest was good for OS-9. We found everything from ways to change a module's header so it could run a super user process to ways to cause a file manager to modify the user number in a process descriptor inadvertently. Rob Doggett (who was the chief OS-9 programmer at the time) fixed every legitimate security hole we found. The result is that OS-9 is now fairly resistant to attack.

I am still interested in security flaws. I would appreciate mail from anyone who finds a "conforming" flaw. The rules are:

- A flaw is defined as either

[1] Klaus Schmitt, and students in Trier Germany were by far the leading contributors.

  - a way to make a non-super user process become super user or gain super user privileges
  - a way for a non-super user process to execute arbitrary code in system state.

- The security flaw must be demonstrated on a development kernel with SSM running full protection.
- It must not use any non-standard system state code.
- It must not rely on any hardware other than the CPU, MMU, and ordinary I/O chips.

22.1 System State

Even with the atomic kernel, OS-9 maintains separate system and user states. If a user-state process attempts to use a privileged instruction (such as `moves`) it will take a privilege violation exception. If it tries to use an SVC that is only available from system state, the kernel will return an E$UnkSvc error.

This is enough protection to catch some programmer errors, but it does not protect against wild pointers or malicious programmers.

The security level of the atomic kernel is appropriate for a system that will run an embedded application. Imagine an automatic teller machine running OS-9. You might think that a criminal could, with suitable in-depth knowledge of OS-9, use control-C to get to a shell and cause the bank great pain. Wrong. There might be a way to access the programming of the ATM from its keyboard, but it will be a mechanism designed by the ATM's manufacturer or the bank. It certainly has nothing to do with OS-9.

Embedded systems take care of their own security and generally implement a level of security that general-purpose computers can't approach without becoming seriously user-hostile. Since an embedded system is not expected to run anything but trusted software, security support by the operating system is not very useful after development is complete.

22.2 User/Group Security

The central difference between a multi-tasking operating system and a multi-user operating system is that the multi-user operating system can identify different users and assign them rights according to their identities.

In most cases both the user and group numbers are used for security checks. A process may only send signals to other processes running under the same user and group. Alarms may only be deleted by processes running under the same group and user as the process that created them.

The version of OS-9 that ran on the 6809 processor supported 256 users and 256 groups. Since this allowed at least 256 different people to have identities on the computer it seemed quite sufficient for a computer with a 16-bit address space.

The 68000 version of OS-9 supports 16-bit user and group numbers. Everyone in a good-size town could have a unique user ID. However, to support compatibility with 6809-era disks, only the low-order eight bits of the user and group number are associated with disk files. Practically speaking, this concession to compatibility limits OS-9 systems to 256 users unless file system security can be overlooked or they use a file system other than RBF.

22.2.1 Module Security

Modules have separate permissions for user, group, and all. This lets a module exercise considerable discretion in its permissions. It can, for instance, limit execution to processes in a selected group, but permit any process to read it.

Not only are modules protected according to their user and group, they can also effect the user ID of processes running from them. Processes always start under the same user and group as their parent, but they can switch to the user and group of the process' main module. This lets trusted programs change or increase their access rights.

The owner of some semi-secret files could create a program that gives certain other users read access to a number of files. The program might check the user's ID against a list of favored users. It might log the read request in a file. It might check the time of day and the device name of the user's terminal. When it is satisfied with the security situation it can issue an `F$SUser` to the module owner's user and group and read the file. A program demonstrating this technique is presented in section 22.7.1.

Modules owned by any user in the super group are special. These modules can have the system state attribute and run as system state processes. Processes running from super group program modules can also change their user ID to *any* value. That is how programs like ***login*** work.

22.3 Super Access Rights

Few people would want to read protect a file so strongly that it could not be saved in a routine backup procedure. There are times when a system administrator needs to kill all the processes on a system as an alternative to rebooting. Formatting a disk is a wonderfully effective way to destroy all the data stored on it, but sometimes formatting is necessary (even for hard disks). How should the OS test processes to see if they

Table 22.1: Super Group Privileges

System call	Action
F$Alarm	Delete any alarm (if open alarm deletion is enabled in the init module)
F$DFork	Debug a module owned by super group
F$Link	Ignore all module access protection
F$Send	Send a signal to any process
F$SetSys	Change system global values
F$SPrior	Change priority of any process
F$STime	Set system clock
F$SUser	Change user ID to any value
F$Load	Load modules owned by super group regardless of the file's owner.
I$Open	Open entire device (@) for reading or writing. Any process can read the first few sectors of the disk. Only the super group can read the entire disk and only the super group can write anywhere to the "entire device."
I$Open	Treated as owner of all files
SS_FDInf	Read file descriptor for named file
SS_FD	Update file owner
SS_Attr	Treated as owner of all files

should be allowed to execute in system state, and who will maintain the password file? (Anyone who can read the file will see all the passwords.)

A system needs a special class of user to do system administration. This is the super user, 0.0, and the super group, 0. Any user in the super group is fully empowered for system administration, but only user zero in the super group can debug system code.

22.4 SSM Security

Without a memory management unit and the supporting software all security measures are somewhat futile. When a process can write into any process' private memory and even into system data structures everything is fundamentally open. In some cases this is an advantage. Processes can interact with one another and inspect OS structures efficiently. It's easy for a user state process to do polled I/O on a system with no SSM.

With a functioning MMU, processes are isolated in their own memory for better or for worse. Pipes, data modules, and other OS-mediated paths between processes provide relatively safe communication, but sometimes more is required.

22.4.1 Using **F$Permit**

The F$Permit SVC gives a super group or system state process access to any address range that would be available if there were no MMU. The call takes three arguments: block size, block address, and access permission. It doesn't return anything unless the call fails.

F$Permit won't let a process give another process access to its data or let a third process manage memory shared between other processes. Unless it is called from system state F$Permit only maps memory into the caller's address space. This is a powerful tool. A process can pass a data pointer to its children, and the children can map that memory and use it to share data without using a data module. A process can use a frame grabber by mapping the frame buffer into its memory.

Here's a program that just maps the directed chunk of memory into its memory and writes it to standard output. It uses the I/O modes header file to define read (and write and execute) mode because the I/O modes are coded the same way as the memory access modes.

One tricky part of the UCC F$Permit binding is that it includes a parameter for the process ID. This parameter is ignored.

```
 #include <stdio.h>
#include <process.h>
#include <types.h>
#include <modes.h>
#include <errno.h>
#include <limits.h>
#include <const.h>

/*
   mapit <length> <address>
   Expect length and address on the command line.
   The address field coded in hex.
   Write the specified range of memory to standard out.
   Since F$Permit must be called by a super group process this program
   changes its user ID before it calls Permit. This means that the program
   module and the file it comes from must be owned by the super group.
*/

main(int argc, char **argv)
{
   void *ptr, *ptr2;
   u_int32 size;
   owner_id user;
```

```
    if(argc != 3){
        fprintf(stderr, "Mapit requires an address and a length\n");
        exit(1);
    }

    if((size = atoi(argv[1])) <=0){
        fprintf(stderr, "Size must be at least one\n");
        exit(1);
    }
    ptr = (void *)strtoul((const char *)argv[2], (char **)&ptr2, 16);

    user.group_user = 0;
    if((errno = _os_setuid(user)) != SUCCESS){
        perror("changing to super user");
        exit(errno);
    }

    /*Last parameter is ignored on OS-9 */
    if((errno = _os_permit(ptr, size, FAP_READ, 0)) != SUCCESS){
        perror("Failure in permit");
         exit(errno);
    }
    fwrite(ptr, size, 1, stdout);
    exit(0);
}
```

Warning

Using F$Permit to share memory that is not in a data module is convenient, and sometimes it is a good choice, but it is a dangerous practice. If a process gives itself access to another process' data area it *must* take care that the memory continues to be allocated to that process. If the other process terminates, or returns the shared memory for some other reason, the memory will drop into the kernel's free pool and be re-allocated for some other purpose. The kernel won't tell other processes sharing the memory that its status has changed. The results can be anything from strange program output to a crashed system, or even corrupted disk files.

22.4.2 Using F$CpyMem

Non-super processes that need access to memory that does not belong to them can use the F$CpyMem SVC. F$CpyMem is safe compared to F$Permit. It only permits the caller to copy arbitrary memory into its local memory. It does not offer a mechanism for writing into arbitrary memory.

F$CpyMem calls for the process ID of the external memory's owner. This parameter will be crucial if OS-9 ever starts to use address relocation hardware, but for the time being it is ignored. Any value works fine. Still, if you know the process ID that owns the data it is good to supply it. One day OS-9 level two may appear and you will be ready.

If you need to see the contents of the low memory, the following tiny program can help.

```
#include <stdio.h>
#include <process.h>
#include <types.h>
#include <errno.h>
#include <const.h>

#define BUF_SIZE            1024

main()
{
    char buffer[BUF_SIZE];

    if((errno = _os_cpymem(0, 0, buffer, BUF_SIZE)) != SUCCESS){
        perror("Copying low memory");
        exit(err);
    }
    fwrite(buffer, BUF_SIZE, 1, stdout);
    exit(0);
}
```

Make certain to pipe the output of this program through ***dump***.

22.5 System Administration

Many OS-9 development systems are single user systems. There's little need for security because they can only be used by people who have physical access to the machine, and in most cases minimal security is plenty. On this type of single-user system, system administration includes decisions about format protection, backup policy, and the amount of memory to allocate to RAM disk and pre-loaded modules. It doesn't generally include a lot of concern about passwords.

A multi-user system needs more careful administration. The administration of system security breaks down into several parts:

Table 22.2: Protection of Files in SYS

Owner	Permissions	File Name
1.1	—-r–r	SrcDbg.hlp
1.1	—-r–r	TermSet
0.1	—-r-wr	backup_dates
1.1	—-r–r	errmsg
1.1	—-r–r	errmsg.short
1.1	—-r-wr	moded.fields
1.1	—-r-wr	motd
0.0	——wr	password
1.1	—-r-wr	termcap
1.1	—-r–r	umacs.hlp

Password file the password file includes passwords in plain text. The least a concerned administrator should do is to permit only owner read and write of the password file and set its user to 0.0. The most an administrator could do is to replace the ***login*** utility with a different program that uses trap door encryption to protect the passwords.

Super user programs may be dangerous. Programs that must run from a file owned by the super group, or programs modules in ROM that are owned by the super group are potentially dangerous. Processes running a program module owned by the super group can become super user processes and do almost anything.

After you know the program modules are all safe, worry about the files they come from. Anyone can create a module that says it is owned by the super group. The system is protected because these super modules can only be loaded from a file owned by the super group. A file that is owned by the super group and is publicly writable is a problem waiting to happen. The contents of the file can be replaced with a trojan horse.

I start by giving all the files in the commands directories public execute and owner execute and read permission. The files in the SYS directory need to be considered individually, but the attributes in table 22.2 are a good start. The principle of minimum access applies here. Only files that need to be in the super group are there.

Format protection *Format* can only be run by the super user, and it can only be run on device descriptors that are not format protected. The *format* process must be in the super group because *format* reads the entire raw disk in its verify stage, and writes to the beginning of the disk when it places the logical format on the disk. Only the super group can read beyond the first few sectors on the disk or write anywhere on the raw disk.

If you find this restriction onerous, a special program can give limited access to *format* to non-super users. (See section 22.7.2.)

22.5.1 Viruses

Virus protection on those systems that are known to suffer from viruses generally includes avoidance, detection, and removal. Viruses can be avoided by not exposing the system to untrusted media. Detection is usually implemented by a program that searches memory and the disk for the fingerprints of known viruses. The removal process depends on the virus, but formatting the disk and restoring from known-clean data is hard to beat.

It's hard to prescribe an anti-virus system for OS-9 because I have never seen an OS-9 virus. That is not as strong an assurance as it may seem. It does not mean that OS-9 viruses don't exist, but only that they've never crossed my path. The safe attitude is to behave as if OS-9 viruses were a serious concern.

There is a hierarchy of exposure levels. Some systems live in essentially sterile environments. The riskiest systems stand open to such a hostile environment that a virus would represent wasted effort on the part of the attacker.

- Systems that are never exposed to foreign software that could change their system software are inherently immune to viruses. The vector for the virus is not present.

- ROM-based systems can only be compromised by modules loaded after boot time.

- Systems that don't load system-state or super group modules are hard to compromise.

- When SSM is fully enabled it protects against most accidental and malicious attacks including viruses. An SSM-equipped system is mainly vulnerable to viruses when it is running super user processes.

- PCF has no file security.

- If un-trusted programs are run from the super group, the user is placing system security in those non-trusted hands.

- Boot time is the system's least-defended period. Booting from a mystery disk or tape is potentially dangerous. Fortunately this is unlikely. An OS-9 boot is system dependent.

An OS-9 system does not have a BIOS. The I/O support in the boot ROM is too limited for a normal virus, and in any case ROM I/O is only available from system state. Viruses tend to rely on the standard PC hardware and the BIOS. Neither of these is present on an OS-9 system. Even various models of the highly-standardized CD–I line of hardware differ significantly below the OS interface.

Let's assume that a virus has somehow infected an OS-9 system. Some system or super group module has been modified and now carries the virus. An ordinary user's module might be infected, but it would be a minor concern. It would only be able to spread itself within that user's universe. The changed module is likely to have a changed size, CRC, or module header parity. The module *could* be modified without changing any of these quantities or noticeably changing the normal function of the module, but that would be difficult. A simple virus detector could look through ***mdir -e*** output for unexpected changes. A complex virus detector would add a cryptographic checksum of each module to the above quantities. A virus creator would know the module construction rules, but if you pick your own checksum algorithm, the creator would need to have inside knowledge about your installation to even start designing a virus that could avoid the size, CRC, and parity checks together with the site-specific checksum.

22.6 Common Security Problems

Small OS-9 systems usually have user IDs less than 256, but networks—especially networks that include NFS links to Unix—often cross the 256-user limit. Since RBF files store the low-order 8 bits of the 16-bit user and group numbers, 256 groups will all appear as the super group to RBF; e.g., \$0000, \$0100, \$0200,…,\$FF00. The only true solution to this problem will require a new RBF disk structure.

If public read access is enabled for the password file, programs can map between user ID and user name. This is a useful feature, but a publicly readable password file means that all passwords are visible everywhere. Making the password file publicly readable is easy, but not necessary. There are at least three secure ways to make password file information available:

- Create a publicly-readable file that contains information extracted from the password file.
- Build a utility that switches itself to group zero and copies selected fields from the password file to standard output.
- Replace ***login*** with a program that can handle encrypted passwords and encrypt the passwords in the password file. Once the passwords are encrypted the file can be made publicly readable.

22.7 Programs

22.7.1 ReadFile

This program implements a non-standard security protocol, that may permit the user to read a file that is normally protected against him.

The program module must be owned by the same user and group as the secret file, or by the super group. If the file is owned by the super user, the program module can only be loaded from a file owned by the super user.

```
#include <stdio.h>
#include <process.h>
#include <types.h>
#include <const.h>
#include <errno.h>

typedef u_char boolean;
#define TRUE       1
#define FALSE      0

#define MY_USER              1
#define MY_GROUP             1
#define LOGFILE              "/h0/sys/accesslog"
#define SECRET               "/h0/peter/secret"

/*
    Prototypes
*/
boolean CheckID(u_int16 group, u_int16 user);
int32 ReadFile(void);

main(int argc, char **argv)
{
    process_id procid;
    u_int16 priority, group, user;
    owner_id user_id;
    FILE *log;

    if((errno = _os9_id( &procid, &priority, &group, &user)) != SUCCESS){
        perror("Calling _os9_id");
        exit(errno);
    }

    user_id.grp_usr.grp = MY_GROUP;
    user_id.grp_usr.usr = MY_USER;
    _os_setuid(user_id);

    if(CheckID(group, user)){
        log = fopen(LOGFILE, "a");
        fprintf(log, "Successful access attempt by user %d:%d\n",
                group, user);
        fclose(log);
        exit(ReadFile( ));
    }else {
        /*
            Don't bother to check for errors on log because there is no way to report
            them or recover from them.
        */
        log = fopen(LOGFILE, "a");
        fprintf(log, "Invalid access attempt by user %d:%d\n",
                group, user);
        fclose(log);
        exit(1);
    }
}


/*
    Ignore group, but check the user against a list of valid users.
*/
boolean CheckID(u_int16 group, u_int16 user)
{
static u_int16 AccessList[ ] = {0, 1, 2, 5, 6, 10, 21, 102};
    static int ListLength = 8;
    int i;
    for(i = 0 ; i <ListLength; ++i)
        if(user == AccessList[i])
            return TRUE;
    return FALSE;
}


int32 ReadFile( )
{
    FILE *path;
    int c;
    if((path = fopen(SECRET, "r")) == NULL){
        perror("Reading secret file");
        return errno;
    }
    while((c = getc(path)) != −1)
        putchar(c);
    fclose(path);
    return 0;
}
```

22.7.2 Format_d0

This program lets any authorized user format disks on /d0. This is normally restricted to super group processes, but this program implements a different policy.

Format_d0 can be run without arguments, or it can accept any argument that works for ***format*** except the device name. The device name is fixed at /d0.

The format_d0 module must be owned by the super group, and it must be in a file owned by the super group. The easiest way to make this work is to have the super user compile the program. If it is to be useful, the executable file should be have public execute permission on. (But not public write permission.)

```
#include <stdio.h>
#include <process.h>
#include <types.h>
#include <const.h>
#include <errno.h>

typedef u_char boolean;
#define TRUE   1
#define FALSE  0

#define SUPER_GROUP        0
#define FORMAT_USER        10
#define CMDLINE_LEN        256


/*
    Prototypes
*/
boolean CheckID(u_int16 group, u_int16 user);

main(int argc, char **argv)
{
    process_id procid;
    u_int16 priority, group, user;
    owner_id user_id;
    int i;
    char CmdLine[CMDLINE_LEN];

    if((errno = _os9_id( &procid, &priority, &group, &user)) != SUCCESS){
        perror("Calling _os9_id");
        exit(errno);
    }
    if(CheckID(group, user) == FALSE)
        exit(1);

    user_id.grp_usr.grp = SUPER_GROUP;
    user_id.grp_usr.usr = FORMAT_USER;
    if((errno = _os_setuid(user_id)) != SUCCESS){
        perror("Changing to super group");
        exit(errno);
    }

    strcpy(CmdLine, "format /d0");
    for(i= 1; i< argc; ++i){
        if((strlen(CmdLine) + strlen(argv[i]) + 2) >CMDLINE_LEN){
            fprintf(stderr, "Oversized command line\n");
            exit(1);
        }
        strcat(CmdLine, " ");
        strcat(CmdLine, argv[i]);
    }
    exit(system(CmdLine));
}



/*
    Check user/group against a list of valid users.
*/
boolean CheckID(u_int16 group, u_int16 user)
{
    static u_int32 AccessList[] = {0x00000000, 0x00010001, 0x00010002,
            0x000a0050, 0x00090026,
            0x00010020, 0x00020001, 0x0005006f};
    static int ListLength = sizeof(AccessList)/sizeof(u_int32);
    int i;

    for(i = 0 ; i <ListLength; ++i)
        if((user |(group << 16)) == AccessList[i])
            return TRUE;
    return FALSE;
}
```

Chapter 23

Customizing OS-9

The ultimate descriptor in OS-9 is the init module. You can think of it as the OS-9 descriptor.

23.1 The Init Module

The OS-9 coldstart code consults init. Fields in init tell the coldstart how much memory to allocate for internal tables. Initial values for the scheduler come from init. The name of the first program to run, an initial default directory, and the device it should use for the standard I/O paths are also in init.

Most of the fields in init provide ways to make small adjustments to OS-9. You can adjust it to fit the size of your system, and tune it a little by fiddling with init. The init module is not, however, limited to subtle adjustments. The module-name fields, M$SysGo and M$Extens, can change OS-9 in fundamental ways.

23.2 SysGo

The SysGo module is the best understood and most modified of these modules. It is the first non-system module to be executed, and it's responsible for maintaining the user interface. ***SysGo*** usually forks a shell to run the startup file. When startup is done, ***SysGo*** enters a loop in which it forks a shell, waits for it to terminate, then goes back and starts the shell again. This provides a safety net under the shell. If the shell terminates, ***SysGo*** immediately starts a new shell. This is not an excessive precaution. Users frequently terminate the shell accidentally. If a user hits the <eof> key by mistake while in the shell, the shell will clean up and exit.

The behavior of an OS-9 system can be changed drastically by replacing ***SysGo*** entirely, or altering ***SysGo*** so it starts some program other than the shell. Since the shell forms a user's view of OS-9, replacing it with some other program can make OS-9 seem entirely different. This is a useful option for people who run OS-9 for some specific task. ***SysGo*** can start that task when the system is coldstarted without messing with startup or the shell.

23.3 The Customization Modules

System state is a special, privileged state of both OS-9 and the processor. Some 68000 instructions can only be issued when the processor is in system (supervisor) state, and some OS-9 functions can only be used when OS-9 is in system state. The processor enters system state when it gets an exception (a hardware interrupt, a `trap` instruction or an execution exception such as a bus error or divide-by-zero). The exception transfers control to the OS-9 kernel and enters system state. System state remains in effect until the kernel returns control to a non-system process. The kernel and all the other components of the operating system are only executed in system state.

Any module can run in system state by requesting it in the module header's attribute byte. This is, however, insufficient for many purposes.

- A programmer may need a task accomplished early in the system-startup process.
- If the system code includes a SVC, it must not be removed from memory.
- Modules outside the operating system itself should not alter operating system structures.

The customization modules are system modules. They are called by the kernel as the last part of the coldstart process but before the first process is started, and can do anything the kernel can. Most things that a module might do before any programs are running aren't interesting. A customization module is mainly used to install new supervisor service requests (SVCs). The name of a customization module should be placed in the M$Extens field in the init module.

A customization module should execute the few statements necessary to issue a `F$SSvc` SVC, then exit. The bulk of the module should consist of new SVCs that you can use later. Supervisor services that are provided by the customization module have all the privileges of other SVCs.

Special SVCs installed by a customization module should avoid SVC numbers that OS-9 uses or is likely to use. At this time, the defined SVCs run up to 83, then skip to 128 for the I/O SVC's which end at 147. You could use any unused numbers for your new SVC's, but it would probably be a good idea to leave a wide margin after the nearest standard SVC. Starting at 200 might leave a safe margin.

OS-9 may require several levels of customization, so the coldstart code is able to run any number of customization modules. Provided that they don't clash; for example, by redefining an SVC, there is no difficulty with this. The names of the customization modules can be concatenated in M$Extens with spaces or carriage returns between the module names, and a null to terminate the string. OS-9 calls the modules in the order they are named.

Chapter 24

Atomic OS-9

Atomic OS-9 is a version of OS-9 minus several features that are seldom useful for embedded applications. The result is about ten percent faster and twenty percent smaller than the full kernel.

Both OS-9 and atomic OS-9 are compromises. OS-9 leans toward features. Atomic OS-9 leans toward speed.

24.1 How to Choose

At first it seems easy to select the atomic or full kernel. The full kernel should be used for software development and general multi-user applications. The atomic kernel should be used for embedded applications. On more careful consideration we find that those guidelines oversimplify. If it is used correctly, the full kernel is fast enough for most purposes, and it has comforting security features. For that matter, the atomic kernel with ***RomBug*** works pretty well for development.

A gang of programmers can use an OS-9 system simultaneously. The effects of each programmer's bugs are restricted to that programmer's environment by OS-9's various security mechanisms. The same mechanisms add security to real-time applications. An OS-9-based system can let end users log in and program around the fringe of the system with reasonable assurance that they won't cause serious trouble. The software that supports robust time sharing supports field-programmable real time systems. It also constitutes a safety net for any type of program.

I've read that all programs of any substantial size contain bugs. I'm not sure where the line is, but I believe that at some level complex applications become impossible to completely validate. Real-time software is especially tricky since it depends on a real-world interface. The best we can do is build modular software, validate the modules individually and in combination, then design the system to isolate and possibly heal any failure. This degree of isolation requires strong protection mechanisms.

- Uninitialized data can turn into a bad pointer. With SSM, the damage from that bad pointer is localized to the process that uses it. If that process has a bus fault STrap handler, it may even be able to recover from the error.
- Unexpected input can cause a process to burn CPU time in an infinite loop. With a scheduler that supports time slicing, that process will probably use more CPU time than expected, but other processes will continue to run.
- A process may suffer an unrecoverable error and scramble its data space. It has no choice but to exit immediately. Since the operating system tracked all the resources allocated to the process, it reclaims all resources. The clean-up job is not perfect—the OS cannot anticipate application-specific termination requirements (like deleting temporary files)—but the system is left in good working order.

OS-9 protects modules fairly well; not as well as a heavy-weight operating system like Unix or VMS, but well enough to protect nicely against non-malicious damage. A system that can support a dozen or more concurrent programmers (buggy-program testers) is over-qualified for occasional bug isolation.

There is no reason to complain about protection itself (unless it cannot be disabled), but the cost of protection is a separate issue. Each factor in a secure system has an associated cost. Without an MMU the operating system has no reliable defense against bad pointers. Unfortunately an MMU is sometimes an expensive separate chip, often adds a clock cycle to each memory access, and always adds overhead at each context switch when it is in use. Multi-user support calls for special code in many system calls to ensure that programs don't access resources that don't belong to their owner. Running processes in user state is the first step toward security, but it forces processes to use system calls to reach basic services like interrupt masking and cache control.

For many applications, application designers would like the opportunity to trade some of OS-9's protection for additional performance. That's a reasonable wish. You'll find OS-9 in automatic teller machines, traffic lights, robots, image analysis systems, and scientific instruments. Since these systems don't have users in the usual sense, the multi-user features of OS-9 are nearly useless.

Atomic OS-9 gives up a large portion of OS-9's safety net and gets extra performance and smaller size in return. It was designed with the following ground rules:

- Only features that cost noticeable performance or memory should be removed.
- Features that primarily support multi-user program development don't belong in all embedded kernels. Only the requirements of embedded systems justify inclusion of a feature in atomic OS-9.

- When the added modularity is not too inefficient, features should be moved out of the kernel into other modules. That adds flexibility and reduces waste.
- Predictable response is even more important for the atomic kernel than it is for the full kernel. The atomic kernel emphasizes predictable response.

The result of the compromise is:

- About 20 percent smaller than OS-9.
- Ten to twenty percent faster on most SVCs. (Though the atomic and full kernels have the same interrupt response time.)
- Some SVCs are more predictable under Atomic OS-9 because system tables don't expand dynamically.

24.2 It's Not a Development System

All processes on the atomic kernel run as super user, there is no system accounting, no SSM protection, and no kernel support for debugging. As a software development OS, the atomic kernel is almost as bad as PC-Dos.

24.2.1 But Development is Possible

It is much easier to debug user-state code under the full kernel, but it is *possible* to debug under the atomic kernel. ***ROMBug*** and the ROM debugger work equally well with either kernel.

The ROM debuggers debug at the assembly-language level and they are not aware of processes. The implications of losing C-source debugging are pretty clear. The effect of losing track of processes may be less obvious. Without process-awareness a breakpoint in a module will affect every process that executes that module. For embedded systems, this problem is generally theoretical. In most cases bugs can be localized to a module instead of a process.

It may actually be an advantage to have all control flow through the debugged code exposed. With an ordinary debugger, a breakpoint will only affect one process. With ***ROMBug,*** you can inspect every process that executes a chosen instruction.

Much of the mechanism for ***Srcdbg*** and ***debug*** is in the full kernel. The kernel arranges to install breakpoints in modules when debugged processes are executing the module and remove them when other processes use the module. It catches interesting events (like signals and exceptions) and reports them to the debugger. It even handles the details of tracing. The atomic kernel does none of this.

Table 24.1: User-State System Calls

SVC	Kernel		IOMan		Other
	Full	Atomic	Full	Atomic	
F$Alarm	X				
F$AllBit			X	X	
F$CCtl③	X	X			SysCache
F$Chain	X	X			
F$CmpNam	X	X			
F$CpyMem	X	X			
F$CRC	X	X			
F$DatMod	X	X			
F$DelBit			X	X	
F$DExec	X				
F$DExit	X				
F$DFork	X				
F$Event	X	X			
F$Exit	X	X			
F$Fork	X	X			
F$GBlkMp	X	X			
F$GModDr	X	X			
F$GPrDsc	X	X			
F$GSPUMp	X				SSM
F$Gregor	X	X			
F$ID	X	X			
F$Icpt	X	X			
F$Julian	X	X			
F$Link	X	X			
F$Load			X	X	
F$Mem					
F$Permit③	X				SSM
F$PErr			X	X	
F$Protect③	X				SSM
F$PrsNam	X	X			
F$RTE	X	X			
F$SchBit			X	X	
F$Send	X	X			
F$SetCRC	X	X			
F$SetSys	X	X			
F$Sigmask	X	X			
F$SigReset	X	X			
F$Sleep	X	X			

③: Some SVCs are called by the kernel but rely on an outside module

Table 24.2: More User-State System Calls

SVC	Kernel		IOMan		Other
	Full	Atomic	Full	Atomic	
F$SPrior	X	X			
F$SRqCMem	X	X			
F$SRtMem	X	X			
F$STime	X	X			
F$STrap	X	X			
F$SysID①	X	X			
F$SUser②	X	X			
F$SysDbg	X				
F$Time	X	X			
F$TLink	X	X			
F$Trans	X	X			
F$UAcct③	X				User-provided
F$UnLink	X	X			
F$UnLoad	X	X			
F$Wait	X	X			

①: SysID is less complete on the atomic kernel
②: Some SVCs complete but do nearly nothing
③: Some SVCs are called by the kernel but rely on an outside module

Table 24.3: I/O System Calls

SVC	Kernel		IOMan	
	Full	Atomic	Full	Atomic
I$Attach			X	X
I$ChgDir			X	X
I$Close			X	X
I$Create			X	X
I$Delete			X	X
I$Detach			X	X
I$Dup			X	X
I$GetStt			X	X
I$MakDir			X	X
I$Open			X	X
I$Read			X	X
I$ReadLn			X	X
I$Seek			X	X
I$SetStt			X	X
I$Write			X	X
I$WriteLn			X	X

Table 24.4: System-State System Calls

SVC	Kernel		IOMan		Other
	Full	Atomic	Full	Atomic	
F$AllPD	X	X			
F$AllPrc	X	X			
F$Aproc	X	X			
F$DelPrc	X	X			
F$FindPD	X	X			
F$FIRQ	X	X			
F$IODel			X	X	
F$IOQu			X	X	
F$IRQ	X	X			
F$Move	X	X			
F$NProc	X	X			
F$Panic③	X	X			User provided
F$RetPD	X	X			
F$SSvc	X	X			
F$VModul	X	X			
F$AllTsk③	X				SSM
F$ChkMem③	X				SSM
F$DelTsk③	X				SSM

③: Some SVCs are called by the kernel but rely on an outside module

I think SSM is the atomic kernel's most painful loss. Often I leave stack checking and debugging assertions in "fully-debugged" C programs. I have a superstitious belief that crowds of bugs are hidden somewhere and will sneak out if I let my program's defenses down. SSM is a defense against bugs, but unlike most bug-detection measures, it protects against bugs in other code. SSM is a strong barrier between the bugs in a program and the rest of the system.

The atomic kernel cannot use an SSM module to provide memory protection, but it does support an SSM to maintain a common page table for all processes.[1] This page table is initialized with all the memory known to the system. Subsequent F$Permit SVCs can add address ranges to the page table for I/O devices and other things that are not normal allocatable memory.

24.3 Fixed Table Sizes

OS-9 can dynamically increase the size of most of its kernel tables. This is convenient. It would be annoying to have to shut down a time-sharing system to increase the size

[1] On the 68040, copy-back cache mode can only be turned on from the page table, and the processor runs much faster in copyback mode. If an SSM is loaded with an 040 atomic kernel it can maintain a page table that controls cache attributes for all user-state code. The main cost of this use of an SSM is memory for the page table. Since it is not involved in context switching or memory allocation, SSM avoids its usual degradation of system performance.

Table 24.5: Table Sizes in Init Module

Table	Reasonable Value	Minimum?
IRQ Polling Table	16	yes
Device Table	16	no
Process Table	32	yes
Path Table	32	no
Module Directory	64	yes
Event Table	16	yes
IRQ Stack Size	(long words) 256	yes
Process Descriptor Stack	1500	yes

of the process table or the event table. The millisecond or less that it takes to expand a table that overflows is invisible in an environment full of editors and compilers.

The cost of table expansion is too high for tightly constrained real-time programs so the atomic kernel uses fixed table sizes. The only tables expanded by the atomic kernel are the list of queued signals attached to each process descriptor and the various tables associated with the memory allocator. The size of most kernel tables is fixed by constants in the init module. If a system call causes a table to overflow, the system call returns an error. This does not mean that the atomic kernel imposes fixed limits on application programmers. Table size is bounded only by memory size and sometimes by the limited range of a 16-bit index. The lack of table expansion in the atomic kernel just means that the system designer has to anticipate the maximum size of each table. A new init module is enough to correct any incorrect guesses.

The values in the init module are used by the kernel's coldstart code and ioman's initialization code. The coldstart code checks the values in the init module against what it feels are minimum reasonable values (which are the same as the "reasonable" values in table 24.5). The system can be made to accept lower values than the minimums, but only by patching the kernel.

24.4 Other Things

The accounting SVC is not called by the atomic kernel. I can imagine real uses for it, but the accounting SVC is primarily used for academic exercises like counting the frequency of various system events. For this convenience, the full kernel calls the accounting SVC frequently. Unless the SVC is installed, all those calls just return with E$UnkSVC, but that takes time.

The atomic kernel cannot afford the time to call even an unknown accounting SVC, so every call to the accounting SVC has been eliminatated This shaves a few instructions off almost every OS activity. Standard accounting information is gone too. ***Procs*** reports zero CPU time used, no SVCs, and no I/O activity for all processes. The code to track all these things is not in the atomic kernel.

Only RBF uses the bitmap routines in the kernel. They are relics from the 6809 version of OS-9 where they were used to manage memory and RBF's allocation bitmap. RBF still calls them, but the memory allocator uses other algorithms. It would probably have been best to move the bitmap functions from the kernel into RBF when it was ported to the 68000, but that didn't happen. The full kernel has to maintain compatibility with old code, so even though nobody can find any real code that uses the bitmap functions, the functions have to stay in the kernel. They could be removed from the atomic kernel. The compatibility rule for the atomic kernel dictates that code must be able to move from the atomic kernel to the full kernel without difficulty. For migration in the other direction missing functions are expected. The only remaining difficulty was RBF.

Without IOman, an atomic OS-9 system definitely does not include RBF, so the bitmap routines (F$AllBit, etc.) were moved from the kernel to the atomic IOMan.

24.5 The Atomic Development Cycle

Atomic OS-9 can be used for development in conjunction with the full kernel. This requires an expanded version of the target system—a system with I/O hardware compatible with the target but more memory, I/O, and ideally a little more processor power. The expanded platform can run OS-9 with a convenient debugging environment: source debugger, file system, networking, accounting information, and room to run diagnostic software.

Provided that the application code is written with the limitations of the atomic kernel in mind, the debugged system can be moved from the development system to the target system without change. The same ROMs should execute on either platform.

Given the nature of software, the application will have some bugs that only manifest on the target system. Those bugs can be attacked with weapons ranging from ***ROMBug*** and logic analyzers to LEDs attached to I/O lines.

Figure 24.1: Some Guidelines

	Favors Atomic	Favors Development
Strongly	4k is a lot of ROM. The CPU is loaded to capacity.	The target will support login. The application must be designed to tolerate defects.
Weakly	The only impact of security features is that they need to be turned off.	Serious debugging is done on the target.

Chapter 25

Building a Device Descriptor

Device descriptors are OS-9's reference material for I/O devices. This chapter shows how they are constructed and what they do.

There is a device descriptor for every I/O device in an OS-9 system. As the name implies, each descriptor describes the attributes of a device. They each contain a description of the hardware for a device and other information specific to it. A new terminal port or graphics card will need a new device descriptor. Sometimes, just changing the type of terminal attached to a serial port requires some changes to the descriptor for that port.

Device descriptors contain all that OS-9 needs to know about a device. All device descriptors have some basic information in common: the address of the device, the interrupt vector it uses, the IRQ (interrupt) level and priority, which file manager to use with it, what device driver to use with it, which access modes are valid for the device, and what it is named. Also, there is always a place for a table, called the initialization table, which contains information that the file manager and device driver might find useful.

The contents of the initialization table vary from one kind of device to another. Devices that use the Random Block File manager (e.g., disk drives) have information like the device's stepping rate and the number of sectors per track. The initialization table for devices that use the Sequential Character File manager contains a list of editing characters, baud rate information, the number of lines on a page, and other similar information. A pipe device descriptor only has a device type (PIPE) and the default pipe buffer size in its initialization table.

25.1 How OS-9 Uses the Descriptor

When you first open a path to a device, OS-9 (the IOMan component) refers to the device descriptor. It has to start at the device descriptor because all it has is the name of the device you want to use. The descriptor gives IOMan the names of the file manager and device driver that it should use. If the device is uninitialized, IOMan attaches the device and calls the device driver's init routine with a pointer to the device descriptor.

For all `I$Open` system calls IOMan builds a path descriptor for the new path and copies much of the information contained in the device descriptor into the path descriptor. Then IOMan hands the request to the appropriate file manager with the address of the path descriptor.

A file manager has access to all the information in the path descriptor, but it ignores the device-specific path options. There is no rule governing what the file manager can use, but it generally avoids data that is specific to the I/O device, such as its port-address. The file manager uses the device driver named in the device descriptor to do physical-I/O operations. The driver reads values that might depend on the specific device from the device descriptor and the path descriptor. Some of the values device drivers read from the device descriptor are the device address, baud rate, stepping rate, and parity.

25.1.1 The /dd Device

Various utility programs work best if they know the name of the device that contains the various system directories; such as DEFS, SYS, SPOOL, and LIBS. Programs can run through a litany of common device names—/h0, /d0, /r0—but it is faster for the program and more predictable for the system administrator to always have a device named /dd. By convention, /dd is the default device, and programs look there first for special directories.

The selection of a default device is confusing. System-related code (like ***login***) usually selects the default device named in the init module. Other utility programs usually look for directories in the current directory and on /dd, then on various conventional disk device names; e.g., /h0, /d0, and /r0.

You can name any disk /dd even if it has another name. The /dd device descriptor is usually made by changing the device name from either h0 or d0 to dd. No other change is required. It is a fine idea to have /dd and another device descriptor for the same device both loaded and attached at the same time. IOMan will understand that the two descriptors refer to the same device and treat them like one device.

25.2 Managing Device Descriptors

The device descriptors that come with your system should be adequate to describe your hardware. If the company that sold you the system is doing its job, you will find that your copy of OS-9 has more device descriptors than you need. You may also find a directory of alternate descriptors somewhere on your distribution disk.

OS-9 usually comes with device descriptors for all the hardware you might have. This probably includes surplus disk drive descriptors and terminal device descriptors. If your boot file contains descriptors for floppy drives /d0 through /d3 and you only have one disk drive, the space used for the /d1, /d2, and /d3 descriptors is wasted. You can remove unneeded descriptors by building a new bootstrap without them. If you save the modules on disk, you can load them if you ever need them.

Unless a device is rarely used, it is best to include its descriptor in the boot file. If you include a module in the boot file you can be certain that it will be packed into memory as efficiently as possible, and won't disappear if you unlink it by mistake. Also, the error messages you get when you try to use a device whose descriptor isn't in memory are sometimes hard to understand. I always seem to have trouble with missing descriptors when I am four or five hours overdue for bed. At times like that I only understand the simplest error messages. Sometimes I have gotten myself into a bit of a panic before I realized that the device descriptor was sitting safe on disk.

25.3 Making and Modifying Descriptors

It is sometimes a matter of judgment whether to generate a new device descriptor or use one that you already have. If you have a new serial card, disk controller, or whatever, you will definitely have to make a device descriptor for it. The device address isn't something you can change after a file has been opened. However, small changes to a device's configuration can be accomplished with little effort.

Information in the initialization table can be changed with the I$SetStt service request. The change isn't actually made to the device descriptor, just to the path descriptor's copy of the initialization table. If you aren't certain you want to make the change permanent, this is the way to do it.

If you choose to go the I$SetStt route you still have a few choices. You can do it all by yourself with a piece of code like:

```
          moveq  #0,D0           Standard input path number
          moveq  #SS_Opt,D1      Select the Read option getstat
          lea    OptBuff(A7),A0  Point at 32-byte buffer
          OS9    I$GetStt        Issue SVC
          bcs    IOError         If error; deal with it
***************
```

```
* Just by way of example let's turn on XOn/XOff
*
            move.b  #$11,PD_XON-PD_OPT(A0)  XOn
            move.b  #$13,PD_XOFF-PD_OPT(A0)  XOff
            moveq   #SS_Opt,D1        SetStat
***************
* D0 and A0 are still set from the previous call
*
            OS9     I$SetStt          issue the SVC
            bcs     IOError
***************
* All set
```

If you mean to change the characteristics of a device in the middle of a program, a I$SetStt is surely the way to do it; but, since the change is only to the path descriptor, the change goes away when the path closes. Even this isn't as simple as it seems. The standard I/O paths are normally all "dups." The I$Dup call is used to give the same path several path numbers. All three standard I/O paths often use the same system path descriptor. Since standard I/O paths are inherited when a process is forked, the change made in this program is passed to the shell (or whatever program forked this one), and perhaps back through several generations. Clearly, path descriptors should be changed cautiously.

Still, the path will eventually be closed, and when that happens your change goes away. If that's fine with you and the device to change is an SCF device, there is an easy OS-9 command, ***tmode,*** which does just this kind of setstat for you. You can turn on XOn/XOff from the shell before starting a program and not have to worry about writing the setstat into it. I assume that you have used ***tmode*** by now; if you haven't, do it soon. There are some values that you can fool with without causing great trouble. Try turning echo off:

```
$ tmode noecho
```

When you are convinced that its no fun typing without seeing the results, turn echo back on:

```
$ tmode echo
```

It's also useful to experiment with pause.

25.3.1 Xmode

If you want to make the change a little more permanent, you have to change the device descriptor. There is no way to change the active copy of a device descriptor in ROM or in a write-protected module, but several programs can modify device descriptors in writable RAM. If the active copy of the device descriptor is not accessible, changes to a copy on disk or the source code are the remaining choices.

The ***xmode*** command makes changes to the initialization table in the device descriptor instead of the copy in the path descriptor. Unlike ***tmode***, it can be used to change the attributes of a device that isn't on one of the shell's standard paths, but like ***tmode, xmode*** only works with SCF devices.

The syntax of ***xmode*** looks a lot like ***tmode,*** but it acts on different control blocks. ***Tmode*** takes effect immediately but may not have a permanent effect. ***Xmode*** only takes effect when a new path to that device is opened, but the change continues in effect for every path opened to that device until OS-9 is rebooted or something else is done to alter the device descriptor.

If you don't have ***xmode*** you can still change device descriptors on the fly. ***Debug*** changes device descriptors as easily as it changes any other type of module (although it would be hard to change path descriptors with it). ***Debug*** can change anything about the descriptor, including the device address and the access mode—values that can't be altered by ***xmode***.

25.3.2 Debug

You've got to keep your wits about you when you use ***debug***. There is nothing to protect you from yourself. If you feel any doubt about it, plan out what you will do before you start. The following is a script for changing the device address for the device descriptor "/t2":

```
$ debug
dbg: l t2                          link to /t2
dbg: d1 .r7+30                     display the port address
00000030+r7 - 00FF 80A0 1B03 0323 0064 0068 0000 0000
dbg: cl .r7+30                     change the port address
00000030+r7:00FF80A0 00FF80a4      to 00ff80a4
00000034+r7:1B030323 .             end of changes
dbg: q                             done with debugger
```

This is sufficient if you don't want to save the descriptor for another session. If you do want to save this modified version of /T2, you need to update its CRC bytes. ***Debug*** changed a byte in the module, and when it is next loaded OS-9 will reject it because the CRC will indicate that the module is flawed. The ***fixmod*** command will repair the CRC:

```
$ save t2 –f=new.t2
$ fixmod –u new.t2
```

One problem still remains. There are now two /T2 modules. One in the boot file, the other in the file new.t2. If you leave things just the way they are, there won't be any way to use the new /T2.

The version of /T2 in the boot can't be removed from memory by unlinking it. All modules in the boot are protected from that. It could be replaced by a module with a higher revision number, but the new version of /T2 you made has the same revision number.

There are two approaches you can take. If you really mean to change the address of /T2, the /T2 module in the boot file will have to be replaced. This can be done with ***os9gen***.

The usual reason for changing the device address in a device descriptor is that there is a new port that needs a descriptor. In that case, what you really needed was a device descriptor with a new name as well as a new device address. You can use ***debug*** to change the name as well as the address, provided that the new name is no longer than the old one. The following ***debug*** statements could have been included at the end of the ***debug*** script for changing the address. They change the module name from T2 to T5:

```
$ debug
dbg: d1 .r7+[.r7+c]l              display the module name
00000070+r7 - 7432 0000 005E 396C 4AFC 0001 0000 0078
dbg: c .r7+71                     change the module name
00000071+r7:32 35                 change 2 to 5
00000072+r7:00 .                  done with changes
```

If the module name needs lengthening, this trick won't work. In fact, the debugger is altogether too cumbersome for most purposes. The only time I use it is when I want to experiment with a modified device descriptor without making any permanent changes.

25.3.3 Module Permissions

If you have SSM, device descriptors are typically read-only. ***Xmode, debug,*** and every other tool that can modify modules in memory will fail with a bus error or some other error. The device descriptor must be made writable before it can be updated. This can be done with ***fixmod*** before the module is loaded, or when the module is created. Module permissions cannot be changed after the module is loaded.

25.3.4 Moded

Moded can modify all types of descriptor modules in disk files—system init modules as well as all types of device descriptors. It itemizes the fields in a module and lets you change them. It may even provide help with information about the meaning of each field. The advantages of ***moded*** are:

- It is easy to use.
- It provides a little protection against improper modification of a module.
- It can modify a module in a file that contains many modules, like a boot file.

Moded is not the perfect tool for module maintenance. It cannot change the length of a module name[1] or modify a module in RAM. It is also unable to even limp through a module type that is not described in the moded.fields file. Since adding a new module type to moded.fields is a serious chore, ***moded*** is not a tool you'll want to use for a quick fix to a module type that isn't already defined.

Moded is a *great* way to modify things like the default process table size in the boot file version of init, or the stepping rate capability of a disk descriptor in the boot file. Before ***moded*** was available, ***os9gen*** was the recommended tool for such modifications. Now simple changes to modules in the boot file are easy to make.

25.4 Building a Descriptor From Scratch

The most powerful, and sometimes the easiest, way to create a device descriptor is with an editor and assembler. Choose the descriptor from the back of the *OS-9 Technical Manual* that is closest to what you need, type it in, making whatever changes are necessary to fit it to your needs, and assemble it. You can also find files in your SYSSRC directory that can make new descriptors with little or no typing. You can test the new descriptor by loading it into memory with the ***load*** command, and doing some I/O to it. If it doesn't perform as you hoped it would, use ***unlink*** to remove it from memory and try again. Don't build a new boot file including the new device descriptor until you are certain it is correct; it's much harder to build a new boot than it is to use ***unlink*** and ***load*** to replace a module that isn't part of the boot.

25.5 The Contents of a Device Descriptor

The values in the device descriptor are all important constants. They are covered in several other places in this book, but perhaps it would do no harm to run through them all together.

The device descriptor starts like any other module—with a module header. The only special part of the module header is the type/language field. The type is $F0, a type set aside for device descriptors. The language is $00, language unspecified.

Following the module header is the port address of the device. The port address is that memory address at which its I/O hardware can be reached. Since 68000-family

[1] ***Fixmod*** can be used to change a module's name to a new name of any length.

processors use memory-mapped I/O, all devices have at least one reserved location in memory.

OS-9 can deal with I/O hardware that isn't interrupt-driven, but it works best when the devices use interrupts to indicate that they need service. The 68000-family of processor supports two ways of identifying interrupts. The processor's handling of auto-vectored interrupts depends entirely on the interrupt's level. Each of the seven interrupt levels might be caused by a list of devices. If there are several possible sources for an interrupt, OS-9 checks each possibility. Loading both the priority and the handling of an interrupt onto the interrupt level is inconvenient for software design, but it makes hardware simpler.

More elaborate hardware can give a vector number (chosen from a range of 192) that identifies the routine that should handle each interrupt. Interrupts from those devices are called vectored interrupts. With vectored interrupts, there are usually enough vectors to give each device its own vector and avoid polling altogether.

The three fields after the port address have to do with interrupt service. The IRQ vector field tells OS-9 which interrupt vector to expect the device to use. Since the higher vectors are for vectored interrupts, this field also tells OS-9 whether the interrupt is vectored or not (although it really doesn't make any difference in the way the interrupt is handled). The interrupt level field tells the driver which hardware interrupt line the device will use. The driver uses this value to mask interrupts to the level of the device. The polling priority is used when several devices share an interrupt vector. Devices with lower priority numbers are placed before devices with higher priority numbers on the list of devices to check when an interrupt arrives.

Then comes the mode byte for this device. This byte can have any of the values used as file access modes:

read	$01
write	$02
execute	$04
public read	$08
public write	$10
public execute	$20
adjust size	$20
shareable	$40
directories	$80

These access mode bits are treated like the attributes of a disk file. When a process opens or creates a file on a device, the device's mode byte is checked to ensure that the device supports the access mode that the process requests.

The next field is the offset from the beginning of the module to the name of the file manager for this device (SCF, RBF, PipeMan, NFM, or whatever). Next is the offset from the start of the module to the name of the device driver for this device (sc68230, rbm20o, etc.).

The next field is the offset to a device-dependent value called the Device Configuration Offset. This could be any value that is convenient to store in a device descriptor. For instance, the device configuration field has been used to store offsets into I/O globals, the names of related modules and events, and device initialization commands.

After the eleven reserved bytes are two bytes that hold the length of the device's initialization table followed by the table. The first byte in every initialization table indicates the class of device the descriptor is for: SCF, RBF, Pipe, Net, or whatever.

25.5.1 SCF Initialization Table

The initialization table for SCF-type files contains all the bytes set by ***tmode*** and ***xmode***.[2] Many of the fields reflect the kind of primitive teletypes in use when OS-9 was born. Today the idea of automatic translation to upper case seems silly, but in the seventies many people had to work with teletypes that only printed upper case and got confused if confronted with lower case letters.

- SCF can translate all lower-case letters to upper case.

- If the backspace character you choose erases the character it moves onto, PD_BSO can be set to zero. If you want SCF to erase the character with a non-destructive backspace, set PD_BSO to 1; SCF will echo backspace-space-backspace for input of backspace. Turning BSO off makes sense if you really do have a destructive backspace, or if you use a hard-copy terminal where printing a space over a character has no effect.

- If you have a hard-copy terminal, backspacing over a line to delete it is ineffective. For these terminals, set PD_DLO. SCF then "deletes" a line by moving to the next line. This might also be useful if you want to keep a record of deleted lines on your screen.

- Echo is a very useful thing to change. With echo on, SCF echoes every input character to the output device. With echo off, SCF echoes nothing. It is good to set echo off from inside programs (like text editors) that want to control what is displayed on the screen, and for slow terminals that can echo locally. Turning echo off cripples SCF's line editing ability, so leave it on by default unless there are strong advantages to having it off.

  Many people recommend echoing locally when the computer is located on the other side of a packet-switched network such as Telenet. Echo time across such a network can be annoyingly long.

[2] One value in the initialization table can't be set by ***tmode*** or ***xmode*** (though it is accessible through ***moded***); the offset to the "2nd device name string."

It is convenient not to echo input to simple prompts. For instance, prompting:

```
Enter y or n:
```

works rather well if you echo a bell character from your program for any character other than y or n. If you let SCF echo, you have to clear the display after each incorrect entry.

- If PD_ALF is non-zero, SCF's formatted output[3] follows each carriage return with a line feed character.

  You may want to set PD_ALF from your programs or in the device descriptor. A program may wish to have some of SCF's line editing power available, but still be able to use carriage return to return to the beginning of the current line.[4] PD_ALF tells the program whether the output device supports that operation (if PD_ALF is non-zero the device probably cannot do a carriage return without moving to the next line), and lets the program turn auto line feed off.

  Many terminals and printers can automatically do a carriage return/line feed when they receive a carriage return. If your output device has this option locked on, SCF lets you turn off automatic line feeds to prevent unintended double spacing.

- Printers, and even some CRT terminals, once needed padding to give them time after they received control characters that caused the print head to move. SCF supports padding after new lines. The value of PD_NUL is the number of bytes of nulls to send after a new line. Non-zero values for PD_NUL are rare with modern output devices.

- Three fields in the SCF device initialization table affect the way SCF pauses output. The idea is that humans seldom read as fast as SCF can display output, so SCF will pause. It pauses after displaying each page (with page length given in PD_PAG) and wait for any character of input before continuing if PD_PAU is non-zero. It also pauses any time it receives the character specified in PD_PSC.

  Page pause is also useful for sheet-fed printers.

- PD_BSP is the character SCF treats as backspace on input. For some terminals this is backspace, for others it is delete. Note that backspace input is separate from backspace output.

[3] SCF uses formatted output for `I$WriteLn` and echoed characters.

[4] It would generally be better to use `I$Write` for the occasional output that should not be exposed to SCF line editing.

Table 25.1: SCF Edit Control Characters

Field	Meaning	Default	
		Hex	ASCII
PD_BSP	Backspace	$08 control-H	bs
PD_DEL	Delete line	$18 control-X	
PD_EOR	End of record (line)	$0d	carriage return
PD_EOF	End of file	$1b	escape
PD_RPR	Reprint line	$04 control-D	
PD_DUP	Duplicate last line	$01 control-A	
PD_Tab	Tab	$09 control-I	tab

- Several other characters in the SCF initialization table are simply editing control characters. For each of these editing characters you may wish to turn the capability off (by zeroing the character), use the OS-9-standard character or choose one that you like. The fields in this class are in table 25.1

- The PD_DUP field is an exceptionally useful editing character. Simply hitting the dup character at the beginning of a line of input will cause SCF to copy the last line of input into your input buffer and onto the screen. You can then edit that line.

  Dup shows very little intelligence and that turns out to be just the right thing. It keeps all input in the same buffer, terminated where the line ends. If you type:

  ```
  $ copy –rx mycmds/beta/research_info /d0/foreddy/research_info
  $ dir –e
  ```

  The second command line has only wiped out the first seven characters of the long copy command. Typing:

  ```
  $ copy –r
  ```

  followed by control-A displays the entire ***copy*** command on the command line ready for editing. You can then backspace to the beginning of "research_info", type "research1.c " over that, type control-A again to display the line to the end, and backspace to change the second file name.

  Line editing sounds confusing, but it isn't difficult when you actually use it. The SCF dup trick isn't as useful as real command line editing supported by the shell would be, but it works everywhere SCF's `I$ReadLn` is used and it is more useful than it looks.

- The keyboard interrupt character causes the device driver to send a SIGINT signal to the last process to read or write the device. If PD_INT is zero, there is no keyboard interrupt character.

- The keyboard abort character is also implemented by the driver. The driver should send a SIGQUIT when it sees this character in input.

  Both keyboard interrupt and keyboard abort are sent by the driver's interrupt service routine. This means that the signals are sent when the character arrives at the device, not when it is read by the process.

- PD_BSE specifies the character that causes the output device to move a position to the left. This is useful for those terminals that want you to type the delete key to backspace, but expect to receive a backspace when they should move the cursor to the left.

- PD_OVF is usually set to the bell character. When a process uses `I$ReadLn` to get input, SCF rejects lines longer than the process requests. Each time the user presses a key that would make the line too long, SCF rejects the character and echoes the PD_OVF character.

- PD_PAR and PD_BAU set the parity and baud rate for the device. The codes are hardware independent. (See the *OS-9 Technical Manual* for the supported codes.) These values are the business of the device driver which goes to some trouble to let processes reset these hardware parameters with `I$SetStt SS_Opt`.

- The second device, PD_D2P, is the device used to echo input. Most terminal ports are set to echo to themselves. If you have a separate keyboard and a graphics display, the keyboard probably should echo to the display.

- The PD_XON and PD_XOFF fields control XOn/XOff processing by the driver. You can set them to unconventional values if your terminal has unusual requirements, or set them to zero if you don't want to use XOn/XOff.

  When my hardware and device driver support it, I prefer hardware flow-control to XOn/XOff.

- The PD_Tab and PD_Tabs fields combine to control SCF's tab processing. If PD_Tab is non-zero, it defines the tab character. When SCF encounters a tab character, it expands it to enough spaces to reach the next tab stop.

  The spacing of tab stops is controlled by PD_Tabs. Typical values would be 4 or 8.

25.5.2 RBF Initialization Table

The initialization area for an RBF device contains information about the type of disk drive attached to it:

- When multiple disk drives are attached to the disk controller, the drive number selects one of the disk drives. PD_DRV is a drive number used for communication between RBF and the driver. For non-SCSI disks, PD_DRV is usually the same as the drive select number for the drive.[5] For SCSI drives, PD_DRV is just a number that must be unique for each drive and less than the maximum number of drives supported by the driver; PD_LUN and PD_CtrlrID select the drive.

- The stepping rate of the drive is entered as a code. Check the *OS-9 Technical Manual* for details.

- If bit 7 (the high-order bit) in PD_TYP is on, the field specifies hard-disk parameters, otherwise it specifies floppy parameters.

  Hard disks are comparatively simple. If bit 6 is on, the disk is removable. There are no other hard disk types. The driver freely caches sector zero if the disk is not removable. If it is removable, the driver can only cache sector zero if it finds a way to invalidate the cache whenever the disk changes.

  For floppy disks, the meaning of PD_TYP is either pre-version 2.4 of OS-9 or post version 2.4.

  For pre-2.4 descriptors the device type field contains two significant bits:

  bit zero Disk diameter

  - **1** eight inches
  - **0** five and a quarter or three and a half inches

  bit five Track-zero density

  - **1** non-standard disk format (double-density track 0)
  - **0** standard format

  In post-version 2.4 descriptors, PD_TYP for floppies contains more information:

  bits 1–3 Disk diameter

  - **0** pre-2.4 descriptor
  - **1** eight-inch physical size

[5] Whether PD_DRV identifies a physical drive is decided by the driver.

2 five and a quarter-inch physical size

3 three and a half-inch physical size

bit five Track-zero density

1 non-standard disk format (double-density track 0)

0 standard format

The definition of PD_TYP is upward and downward compatible. The extra information added at version 2.4 is invisible to pre-2.4 drivers and the bits that the definitions have in common are enough to give old drivers as much information about the disk as they used to get. Old drivers guessed the drive's rotational rate and data transfer rate based on the disk size. New drivers with old descriptors must still derive the rates based on the type information. New drivers with new descriptors look in PD_Rate for rotational and transfer rate and get the actual disk size from PD_TYP. The physical size of the disks is only used to let ***format*** give an accurate message about the physical size of the disk it is formatting.

- If the disk is a floppy, the media density field indicates the recording density:

bit zero Bit density

1 double

0 single

bit one Double track density. The default is single track density, 48 tracks per inch.

1 double (96 tpi)

bit two Quad (1.2M per floppy) track density. (192 tpi)

1 quad

bit three Oct track density (384 tpi)

1 oct

- The number of cylinders is the number of tracks recorded on one side of a disk. This number is usually 35, 40, or 80. For hard disks the number is much larger. For autosize drives (see PD_Cntl), this field is ignored and is generally set to zero.

- The number of sides is one for single sided floppies and two for double sided floppies. Hard disks can have many sides. For autosize drives (see PD_Cntl), this field is ignored and is generally set to zero.

- Verification is usually used for floppy disks. If the disk controller or drive automatically verifies data it has written, verification need not be done. Otherwise it is strongly recommended. If you use good hardware you will seldom have data incorrectly written, but it is worth the check just to be sure. If the verify byte is zero, all writes are verified.

- The number of sectors per track affects how much can be written on a disk. Pushing the number of sectors per track higher than the standard requires excellent hardware, and may be unreliable. Find out what the hardware manufacturer recommends. For autosize drives (see PD_Cntl), this field is ignored and is generally set to zero.

- The number of sectors on track zero is special because, under the standard OS-9 floppy disk format, track zero is always written single density. By keeping the first track single density regardless of the density of the rest of the disk we make it easy for OS-9 to read enough of the disk to learn the characteristics of the rest of it. Since the density of track zero may be different from the rest of the tracks, the number of sectors on it may also differ. For autosize drives (see PD_Cntl), this field is ignored and is generally set to zero.

- The segment allocation size is part of another optimization trick. Most files start small and grow as more data is written to them. If the system is active with several processes writing to the disk, little pieces of files may get scattered around the disk. By making the segment allocation size greater than one, files can be made to start out with several sectors. Any unused clusters will be released when the file is closed. If most files are roughly some multiple of the segment allocation size, nice non-fragmented files are the result. Programs can request non-standard initial allocations when they open a file. The default is only important for programs that don't use this feature.

- Sector interleaving is a trick to improve performance. If sector two is written directly after sector one on the disk, there may be a serious performance penalty. After the computer reads the first sector in a file, there is usually a tiny pause before it requests the second sector. If the pause is longer than the amount of time it takes the disk to cross the boundary between the first and second sectors, the disk must spin all the way around before the second sector can be read. By putting some other sectors (say the eighth and fifteenth) between the first and second, we give the program time to process the first sector and ask for the second before the sector arrives under the disk's head, ready to be read. The interleave factor specifies how many sectors apart sequentially numbered sectors should be located.

- The Direct Memory Access (DMA) byte may be used to specify DMA[6] options. The use of PD_DMA is defined by the driver, and since DMA seldom has options, PD_DMA is usually ignored. This byte is not usually used to turn DMA on and off.

- Track base offset is the physical track number of the first accessible track on a disk.[7] Universal format uses a track offset of one to escape any special significance of track zero. A track offset of one will map logical track zero to physical track one. This wastes a track of disk space, but avoids constraints that the controller or driver might place on track zero.

- Sector base offset is the physical sector number of the first accessible sector. It can be used like the track base offset. Several common OS-9 disk formats (including the universal format) require a sector base offset of one. This offset is required by floppy disk controllers that only work well when sector numbers start at one. The original RBF physical disk format was designed for disk controllers that could start each track at sector zero. A sector offset of one will map the sector numbers from one of these IBM-style controllers into the zero-based array that RBF drivers assume.

- The default sector size is 256 bytes, but if the hardware and driver support it, other sector sizes can be specified in the PD_SSize field.

  The PD_SSize field specifies the *physical* sector size. This is the sector size that the driver expects to find on the disk. Drivers and hardware that support variable sector size always use a logical sector size equal to the physical sector size. Deblocking drivers only support 256-byte logical sectors, but they support different physical sector sizes by deblocking; e.g., 512-byte physical sectors are each divided into two 256-byte logical sectors. Less sophisticated drivers just return an error when the physical sector size differs from 256 bytes.

  When variable sector size is supported by the driver and hardware, PD_SSize is used to set the physical sector size when the drive is formatted.

  When variable sector size is supported and PD_SSize is zero, the driver stores the actual sector size in that field.

[6] Devices that support DMA are able to access main memory. Entire blocks of data can be moved between a file and memory with no help from the processor. This feature is implemented by the hardware and the driver.

[7] Many device drivers for hard disks fail to support track base offset. These drivers simply ignore the value without comment. It is best to assume that your driver does not support a track base offset unless you *know* that it does.

The documentation for a driver should specify its degree of variable sector size support.

Zero is generally a good value for PD_SSize. Variable sector size drivers update the value to correspond to the disk, and non-variable sector size drivers ignore the field and use 256 bytes.

- The device control word is a multi-purpose field used to control the features of RBF and the drivers.

  bit 0 Format inhibit. Use this to protect a disk from being accidentally reformatted. The idea is that you should normally use device descriptors that are format protected. If you want to format a disk you have to load a special device descriptor with formatting enabled. This extra step might prevent dreadful mistakes.

  bit 1 Multi-sector I/O is supported. If multi-sector I/O is supported, the PD_MaxCnt field should indicate the number of bytes the I/O hardware and driver can transfer per multi-sector operation.

  bit 2 The disk has a stable ID. It means that the sector zero information maintained by the device driver will be either invalid or correct. (If the sector-zero-read flag is true, the drive table information is correct and the sector zero buffer contains a true image of sector 0.) This requires the driver to be aware of disk changes.

  bit 3 The device size can be determined with SS_DSize, ***format*** will format the entire disk with one write track, and the disk geometry fields (sectors per track, cylinders per device, and so forth) for the device should be ignored.

  bit 4 The device can write a single track. Various disk-repair strategies only work for devices that let a program write tracks.

- An I/O error on a disk is not always repeatable. If you get an I/O error, trying the operation again might work. The Number of Tries field lets you override a driver's default number of tries. In particular it lets you insist on no retries.

- Many computers support a Small Computer System Interface (SCSI) bus. The devices on this bus are intelligent controllers and computers. A device descriptor can describe a device attached to a SCSI controller. The address of such a device contains two numbers in addition to the port address[8]:

[8] A computer can support many separate SCSI connections. The address of the SCSI interface identifies the bus.

  - The SCSI ID of the controller on the bus. A SCSI bus can support up to eight devices (one of which is the computer), each identified by a SCSI ID number. The SCSI controller ID, PD_CtrlrID, is the SCSI ID of the SCSI controller for this device. This value is used by the device driver to address messages to the controller.
  - The logical unit number of the device on the SCSI controller. A single SCSI controller might easily support two hard disks, a floppy disk, and a tape drive. These would be distinguished by their SCSI logical unit number.

- Some disk drives behave differently for the inner and outer tracks. If the controller needs to get involved, it will find values for the cylinder where it should begin reduced write current and the cylinder where it should begin write precompensation.

- Some hard disk drives leave their head resting on the surface of the disk when they stop. This causes extra wear on the part of the disk where the head skids to a halt and takes off again. Important data can be protected by designating a region of the disk as the parking area. Some disk drives automatically move their heads into the parking area when they detect low power. The driver can protect drives that don't park their heads automatically by moving the heads to the cylinder specified in the PD_Park field. Disks can also be parked from outside the driver with the SS_SQD setstat.

- The total cylinders field reflects the number of physical cylinders on the device. If the disk is partitioned, the total number of cylinders is the sum of the cylinders in all the partitions. On a partitioned drive, the number of cylinders in each partition is recorded in the PD_CYL field of the partition's descriptor.

  A disk with a track offset must have PD_TotCyls equal to the track offset plus PD_CYL.

- The LSN offset is also intended for use with partitioned drives. The LSN offset is added to the LSN by the driver before it uses the LSN for anything. The sector offset is a hardware-level constant; it is added to the sector number before the number is written to the controller hardware, but after range checks and so forth.

- SCSI driver options are passed to drivers for SCSI disks. The bits in the field are defined as follows:

  bit 0 ATN asserted (disconnect allowed)

bit 1 Device can operate as a target

bit 2 Synchronous data transfer is supported

bit 3 Parity on

- The PD_Rate field specifies the data rate and rotational speed of floppy disks. It defines data rates from 125k bits/sec to 5M bits/sec and rotational speeds from 300 RPM to 600 RPM. See the manual for details and check the disk drive's manual too before you assume that a particular bit rate corresponds to a rotation rate. Some drives change data rates by changing rotation rate, others don't.

- The PD_MaxCnt field is the maximum number of bytes that can be transferred in one multi-sector read or write. Note that this field specifies a number of *bytes* not sectors.

  RBF divides long multi-sector I/O requests into blocks of no more than PD_MaxCnt bytes.

25.5.3 RAM Disks

OS-9 uses a special RBF driver to manage RAM disks; it is an unusually simple driver. The device initialization entry causes the driver to allocate enough memory to contain a RAM image of an RBF disk, and the terminate entry frees the memory allocated by the initialization routine. The read and write entries simply treat the block of memory as an array of sector images.

Only two option fields in a RAM disk device descriptor are usually non-zero: the number of sectors per track, and the segment allocation size. The number of sectors per track controls the size of the RAM disk, and the segment allocation size primarily controls the minimum fragment size for files. The usual performance considerations are not as much a concern for RAM disks as for mechanical disks.

Since RAM disks use 256 byte sectors, the number of sectors per track is four times the RAM disk's capacity in kilobytes.

Single-user OS-9 systems can benefit from a collection of pre-configured RAM disk descriptors in the commands directory. I usually use a RAM disk with 1536 sectors per track and a segment allocation size of four sectors, but when I am doing exceptionally memory-hungry work I ***deiniz*** the RAM disk to free its 384k, and when I want to compile unusually large programs I sometimes ***deiniz*** the 384k RAM disk and load one with 2048 sectors (512k).

The port address of a RAM disk has two meanings. If the number is less than $400, it simply identifies the RAM disk. The memory for RAM disks with low port addresses is allocated with an `F$SRqMem` SVC when the disk is attached and freed when the device is detached.[9] These RAM disks could be called floating RAM disks because they may appear at a different location each time they are attached.

If the port address is greater than or equal to $400, the port address is the starting address of the RAM disk. This lets the RAM disk be locked into particular memory locations; e.g., non volatile RAM. Memory that will be used for a fixed RAM disk should not be available for general allocation. It can be left out of the memory table in the init module, or given a type and priority that prevents it from being allocated except by a special request.

[9]Yes, it is possible to have 1024 floating RAM disks at the same time. At least two or three RAM disks can be useful.

Chapter 26

File Managers

This chapter is an overview of file managers. Each of the main file managers is mentioned, and the role of a file manager in the OS-9 system is discussed.

File managers are the level between the I/O manager and device drivers. Like device drivers, they hide some aspects of the I/O system from user programs. Some requests are passed on to device drivers with little intervention: Sequential Character File (SCF) `I$Write` requests would be an example. Other requests, such as the Delete request to the Random Block File (RBF) manager, are handled mainly in the file manager with only incidental requests going to the driver. The `I$Seek` request and some GetStat and PutStat calls don't go to the driver at all.

Much of SCF's function relates to line editing. All special characters, like backspace and reprint-line, are handled here. SCF also handles contention between several processes wanting simultaneous access to a device.

RBF is the only part of OS-9 that knows anything about the logical structure of a disk. It handles directories, file descriptors, and the disk identification sector.

Pipeman does everything for pipes; the device driver for pipe files does exactly nothing. The device driver is necessary because IOMan wouldn't tolerate a path without one, but there isn't any actual device associated with a pipe. Pipes are manufactured entirely of mirrors.

Most devices can be fit into the SCF or RBF class. Devices in these classes can be added to an OS-9 system with little effort. At most, a device driver will need to be written, though usually a device descriptor will suffice.

A special file manager called NFM adds local area network support to OS-9. This permits several computers to be attached to each other. Resources like disk space and peripherals can be shared through the network. A single large-capacity disk can serve several computers, saving money on disks and making public files available to users of any computer on the network. Other high-priced peripherals like fast printers and graphics devices are easier to afford when they are shared by several computers on a network.

Networking involves more than a network file manager. Special processes need to run on each networked processor to do what a file manager can't. Still, the network looks just like any other device to a program. The network file manager is not a simple piece of code, but fitting it into OS-9's I/O structure was not a problem.

A file manager called SBF handles devices like tape drives. These devices don't support random access, so RBF can't properly controlled them. SCF isn't appropriate because tape drives handle data in blocks (very like disk sectors). Since streaming tape drives work best when they are fed a steady stream of data, the SBF file manager supports asynchronous I/O. It returns from a write before the data is actually written to the tape. If a program can assemble blocks of data fast enough, it can keep the file manager ahead of the tape drive. This will let the tape drive run without hesitations—a big advantage for streaming tape drives.

A few devices can benefit from an entirely new file manager. OS-9's architecture permits new file managers to be added without any disruption. Several ideas for alternative file managers come to mind.

26.1 Possibilities for New File Managers

An I/O processor file manager to replace SCF was once written for OS-9/6809. Many of the functions of a file manager can be pushed all the way down into a device if the device is intelligent enough. Intelligent controller boards that support terminals and printers have been made. The processor on the I/O board can handle line editing nicely without any help from the file manager. When this function can be placed in the device controller board and the file manager is stripped down to those functions that can't be moved to the controller, the I/O capabilities of the computer increase substantially. Each CPU cycle that can be made the responsibility of the I/O processor is another cycle available for user programs. Taking full advantage of an intelligent SCF device requires a special file manager with line-editing functions removed and possibly some additions to give the controller the information it needs.

RBF can benefit just as much from intelligent controllers as the SCF manager, perhaps more. Functions like file and directory handling—in fact, most of the functions of the RBF manager—could be moved to the controller. A dedicated processor could handle these operations more efficiently than the general purpose processor running the file manager. Even if the microprocessor on the controller is slower than the main processor, unloading functions onto intelligent peripherals returns processor resources to other programs.

It is in the interest of the manufacturers of intelligent controller boards to write special file managers as well as device descriptors for their hardware. The special software makes their hardware look a lot better. Unfortunately, RBF is a good deal more complicated than it seems. The only straightforward way to move RBF's functions into an I/O board is to move RBF there.

A very intelligent terminal would do best with a file manager somewhere between SCF and the network file manager. You want to be able to send programs and non-display data to the terminal as well as normal terminal I/O. A good file manager would normally handle the terminal's special features for you. You could pretend it was a normal terminal. It would also give you a way to get at the terminal if you wanted to do something special to it.

OS-9 has local area networking, but it doesn't yet deal with dialup networks. It's an interesting question whether it will be better to extend the current software to handle phone lines or write a new file manager that supports such protocols as zmodem, and uucp.

There are dozens of other promising opportunities for file managers. A file manager for write-once-read-many-times (WORM) media would be fun to write, so would a file manager for Unix-format disks and a file manager for high-speed serial I/O.

26.2 Writing a File Manager

There is nothing inherently difficult about writing a file manager. The trickiest aspect of the job is that debug and srcdbg don't work for file managers. Three special debuggers can be used with file managers. The ROM debugger is part of an OS-9 PortPak. It is not nearly as powerful as debug, but it is barely enough.[1] The ***Sysdbg*** program is similar to ***debug***, but it works with system modules. ***Sysdbg*** runs from inside OS-9. It can debug system code and it supports features like ***debug***. Once a system is running well enough to load sysdbg and run it, ***sysdbg*** is much easier to use than the ROM debugger.

The best debugger for system state code is ***ROMBug***. It has all the features of ***debug*** and ***sysdbg*** but it uses polled I/O like the ROM debugger and I think it is more reliable than ***sysdbg***.

A file manager has thirteen entry vectors, each pointing to a routine that provides a specific service. All the entry vectors must be there, but the attached routines can be null procedures that only return with carry clear, or routines that set an error code and return with carry set.

If a new device driver will do what you want, don't write a file manager. A file

[1] The ROM debugger can be invoked at system startup, when a processor trap takes place, or when the F$SysCall SVC is used. Access to the ROM debugger is controlled by hardware and software switches.

Figure 26.1: File Manager Entry Points

1	Create
2	Open file
3	Make directory
4	Change directory
5	Delete file
6	Seek
7	Read
8	Write
9	Read Line
10	Write Line
11	Getstat
12	Setstat
13	Close file

manager is usually a much bigger project than a driver; look at the relative sizes of the file managers and drivers included with your system, or the examples later in this book. The device drivers in chapter 29 and appendix D are *real* device drivers written in assembly language. The driver in chapter 30 is a fairly complete driver written in C. The file managers in chapter 27 and appendix C are simplified demonstrations mainly written in C, but they are still bulky programs.

File managers are designed to manage files, but they can be extended to a wide variety of system resources. File managers (with the help of IOMan) associate resources with paths. Paths have two interesting attributes that extend beyond ordinary files:

1. Paths can be inherited by child processes.

2. Paths are automatically closed when the process that owns them exits.

The attributes of paths are essential for files, but they also apply to resources like memory, locks, and names.

A new file manager is about the most important addition that a user can make to OS-9. A new or modified file manager can add new functions to OS-9. A new file manager can be brought into use by adding a device descriptor that references it. Clearly this one of the directions in which OS-9 was meant to be expanded.

Chapter 27

A Simple File Manager

This chapter shows how to build a file manager by walking through a very simple file manager written in C.

The file manager in this chapter is the precursor to the much more complicated file manager in appendix C. This example is not useful in itself but it shows how a file manager can fit between IOMan and RBF device drivers.

The most difficult task for this file manager is interfacing to an RBF device driver. Device drivers are constructed with a particular file manager in mind, and fitting such a specific interface to a different file manager takes care. The trickiest aspects of this interface were the sector size (512 bytes instead of the OS-9 standard 256) and the driver's assumptions about the system sector.

The dummy file manager supports the open, close, and read entry points. All the other entries return a zero as if everything was fine. This is not a recommended practice, but it made the file manager easier to test.

27.1 Using the C Language

Until recently all file managers were written in assembly language; system-level code written in a high-level language is still unusual. The interface specification for a file manager assumes that the programmer has full control of the processor's registers, and that the programmer can insert values at particular spots in the module. It is difficult for a C program to get at the parameters passed in registers, particularly A6, where the system globals pointer is passed. The offset list at the module entry point is also challenging.

The complete list of problems with C for writing file managers is:

- C doesn't support access to registers, but the interface between IOMan and the file manager and the interface to existing device drivers is through parameters passed in registers.

- C doesn't support explicit constants in code. Furthermore, the C entry point is CStart. It definitely doesn't have a vector table at its entry point.
- C programs are slower and larger than equivalent assembly language programs.
- C programs tend to use static storage and initialized storage. Initialization is done by the fork SVC which will not be used for a file manager, and it is difficult to fit C static storage into a file manager's memory model.

A different CStart can deal with the parameter passing and vector table conventions. An assembly language interface routine can set up registers and call the device driver. The static storage problem could be addressed with some fancy linking, but I find it easier to simply avoid static storage. The only remaining problems are speed and size.

If the size of a C program is a problem, fall back to assembly language. A file manager written in C may be two to four times the size of an equivalent assembly language file manager, but that's still under 100K. Most systems can spare the memory. If you can't, use assembly language.

The slower speed of C programs is unlikely to be a problem for most file managers. The I/O rate is slow compared with the processor. Also, it is easier to make algorithm enhancements in C than in assembly language. Algorithm improvements can make performance improvements that bury the cost of high-level-language code.

27.2 A CStart for a File Manager

This version of CStart forms an interface between the kernel's interface to a file manager and the C runtime environment. It uses entirely separate code for each interface to make debugging easier.

```
 ****************************
*
* cstart.a - C program startup routine for a file manager
*


          use      <oskdefs.d>
          opt      –l
00000001  Carry:   equ     %00000001 Carry bit


0000000d  Typ      equ     FlMgr
00000001  Edit     equ     1
00000400  Stk      equ     1024          a default stack size
```

```
00000101 Cerror     equu   257                 arbitrary C error

                    psect  cstart_a,(Typ<<8)!Objct,(ReEnt<<8)!1,Edit,Stk,_cstart

0000000d cr         equ    $0d
00000020 space      equ    $20
0000002c comma      equ    $2c
00000022 dquote     equ    $22
00000027 squote     equ    $27

         *
         * C Program entry point
         *
         * On entry we have:
         *          a1     points to the path descriptor
         *          a4     points to the current process descriptor
         *          a5     points to the user's register stack
         *          a6     points to the system global area
         *
         * To run a C program we must have:
         *          a6     static storage base pointer
         * The static storage is in the path descriptor
         _cstart:
0000 001a           dc.w   _Create-_cstart
0002 0032           dc.w   _Open-_cstart
0004 004a           dc.w   _MakDir-_cstart
0006 0062           dc.w   _ChgDir-_cstart
0008 007a           dc.w   _Delete-_cstart
000a 0092           dc.w   _Seek-_cstart
000c 00aa           dc.w   _Read-_cstart
000e 00c2           dc.w   _Write-_cstart
0010 00da           dc.w   _ReadLn-_cstart
0012 00f2           dc.w   _WriteLn-_cstart
0014 010a           dc.w   _GetStat-_cstart
0016 0122           dc.w   _SetStat-_cstart
0018 013a           dc.w   _Close-_cstart

         _Create
001a 48e7           movem.l a4/a6,-(sp)
001e 2009           move.l  a1,d0
0020 220d           move.l  a5,d1
0022=6100           bsr     Create          (pd, regs, ProcDesc, SysGlobs)
0026 4cdf           movem.l (sp)+,a4/a6
002a 4a40           tst.w   d0
002c 6600           bne     _Error
0030 4e75           rts
         _Open
0032 48e7           movem.l a4/a6,-(sp)
0036 2009           move.l  a1,d0
```

```
0038 220d          move.l   a5,d1
003a=6100          bsr      Open          (pd, regs, ProcDesc, SysGlobs)
003e 4cdf          movem.l (sp)+,a4/a6
0042 4a40          tst.w    d0
0044 6600          bne      _Error
0048 4e75          rts
          _MakDir
004a 48e7          movem.l a4/a6,–(sp)
004e 2009          move.l   a1,d0
0050 220d          move.l   a5,d1
0052=6100          bsr      MakDir        (pd, regs, ProcDesc, SysGlobs)
0056 4cdf          movem.l (sp)+,a4/a6
005a 4a40          tst.w    d0
005c 6600          bne      _Error
0060 4e75          rts
          _ChgDir
0062 48e7          movem.l a4/a6,–(sp)
0066 2009          move.l   a1,d0
0068 220d          move.l   a5,d1
006a=6100          bsr      ChdDir        (pd, regs, ProcDesc, SysGlobs)
006e 4cdf          movem.l (sp)+,a4/a6
0072 4a40          tst.w    d0
0074 6600          bne      _Error
0078 4e75          rts
          _Delete
007a 48e7          movem.l a4/a6,–(sp)
007e 2009          move.l   a1,d0
0080 220d          move.l   a5,d1
0082=6100          bsr      Delete        (pd, regs, ProcDesc, SysGlobs)
0086 4cdf          movem.l (sp)+,a4/a6
008a 4a40          tst.w    d0
008c 6600          bne      _Error
0090 4e75          rts
          _Seek
0092 48e7          movem.l a4/a6,–(sp)
0096 2009          move.l   a1,d0
0098 220d          move.l   a5,d1
009a=6100          bsr      Seek          (pd, regs, ProcDesc, SysGlobs)
009e 4cdf          movem.l (sp)+,a4/a6
00a2 4a40          tst.w    d0
00a4 6600          bne      _Error
00a8 4e75          rts
          _Read
00aa 48e7          movem.l a4/a6,–(sp)
00ae 2009          move.l   a1,d0
00b0 220d          move.l   a5,d1
00b2=6100          bsr      Read          (pd, regs, ProcDesc, SysGlobs)
00b6 4cdf          movem.l (sp)+,a4/a6
00ba 4a40          tst.w    d0
```

```
00bc 6600         bne      _Error
00c0 4e75         rts
        _Write
00c2 48e7         movem.l a4/a6,-(sp)
00c6 2009         move.l   a1,d0
00c8 220d         move.l   a5,d1
00ca=6100         bsr      Write          (pd, regs, ProcDesc, SysGlobs)
00ce 4cdf         movem.l (sp)+,a4/a6
00d2 4a40         tst.w    d0
00d4 6600         bne      _Error
00d8 4e75         rts
        _ReadLn
00da 48e7         movem.l a4/a6,-(sp)
00de 2009         move.l   a1,d0
00e0 220d         move.l   a5,d1
00e2=6100         bsr      ReadLn         (pd, regs, ProcDesc, SysGlobs)
00e6 4cdf         movem.l (sp)+,a4/a6
00ea 4a40         tst.w    d0
00ec 6600         bne      _Error
00f0 4e75         rts
        _WriteLn
00f2 48e7         movem.l a4/a6,-(sp)
00f6 2009         move.l   a1,d0
00f8 220d         move.l   a5,d1
00fa=6100         bsr      WriteLn        (pd, regs, ProcDesc, SysGlobs)
00fe 4cdf         movem.l (sp)+,a4/a6
0102 4a40         tst.w    d0
0104 6600         bne      _Error
0108 4e75         rts
        _GetStat
010a 48e7         movem.l a4/a6,-(sp)
010e 2009         move.l   a1,d0
0110 220d         move.l   a5,d1
0112=6100         bsr      GetStat        (pd, regs, ProcDesc, SysGlobs)
0116 4cdf         movem.l (sp)+,a4/a6
011a 4a40         tst.w    d0
011c 6600         bne      _Error
0120 4e75         rts
        _SetStat
0122 48e7         movem.l a4/a6,-(sp)
0126 2009         move.l   a1,d0
0128 220d         move.l   a5,d1
012a=6100         bsr      SetStat        (pd, regs, ProcDesc, SysGlobs)
012e 4cdf         movem.l (sp)+,a4/a6
0132 4a40         tst.w    d0
0134 6600         bne      _Error
0138 4e75         rts
        _Close
013a 48e7         movem.l a4/a6,-(sp)
```

```
013e 2009             move.l  a1,d0
0140 220d             move.l  a5,d1
0142=6100             bsr     Close            (pd, regs, ProcDesc, SysGlobs)
0146 4cdf             movem.l (sp)+,a4/a6
014a 4a40             tst.w   d0
014c 6600             bne     _Error
0150 4e75             rts
          _Error
0152 003c             ori     #Carry,ccr
0156 4e75             rts
```

The following routines are called from the C component of the file manager. They interface to the device driver and provide functions that are normally found in the C libraries. This file manager avoids the standard libraries to ensure that no static storage references sneak into the file manager code.

```
          * CallRead (ct, lsn, pd, DevStaticS, ProcD, regs, sysglobs)
          * puts
          *           ct in d0
          *           lsn in d2
          *           pd in a1
          *           DevStaticS in a2
          *           ProcD in a4
          *           regs in a5
          *           sysglobs in a6
          CallRead:
0158 48e7             movem.l d2–d7/a0–a5,–(sp)
          * ct is already in d0
          * calculate the entry address in the device driver
015c 226f             move.l  13*4(sp),a1      pd to a1
0160=2069             move.l  PD_DEV(a1),a0  device table entry
0164=2068             move.l  V$DRIV(a0),a0  device driver address
0168=2428             move.l  M$Exec(a0),d2   device driver entry offset
016c=d0f0             add.w   D$READ(a0,d2),a0 Add read-ent offset to module base

0170 2401             move.l  d1,d2
0172 246f             move.l  14*4(sp),a2      DevStatic to a2
0176 286f             move.l  15*4(sp),a4      ProcD to a4
017a 2a6f             move.l  16*4(sp),a5      regs to a5
          * sysglobs is already in a6
017e=4e40             os9     F$SysDbg         look for errors

0182 4e90             jsr     (a0)
0184 6500             bcs     CallError
0188 6000             bra     CallOK


          * CallWrite (ct, lsn, pd, DevStaticS, ProcD, regs, sysglobs)
          * puts
          *          ct in d0
          *          lsn in d2
          *          pd in a1
          *          DevStaticS in a2
          *          ProcD in a4
          *          regs in a5
          *          sysglobs in a6
          CallWrite:
018c 4e75            rts

          * CallGetStat(code, pd, DevStaticS, pd, regs, sysglobs)
          * puts
          *          code in d0
          *          pd in a1
          *          DevStaticS in a2
          *          ProcD in a4
          *          regs in a5
          *          sysglobs in a6
          CallGetStat:
018e 4e75            rts

          * CallSetStat(code, pd, DevStaticS, pd, regs, sysglobs)
          * puts
          *          code in d0
          *          pd in a1
          *          DevStaticS in a2
          *          ProcD in a4
          *          regs in a5
          *          sysglobs in a6
          CallSetStat:
0190 4e75            rts

          CallOK
0192 4cdf            movem.l (sp)+,d2–d7/a0–a5
0196 4280            clr.l   d0
0198 4e75            rts

          CallError
019a 2001            move.l  d1,d0
019c 4cdf            movem.l (sp)+,d2–d7/a0-a5
01a0 4e75            rts

          _srqmem:
01a2 2f0a            move.l  a2,–(sp)
01a4=4e40            os9     F$SRqMem
01a8 6400            bcc     srqmemx1
01ac 70ff            moveq.l #–1,d0
01ae 6000            bra     srqmemx
```

```
             srqmemx1
01b2 200a                move.l   a2,d0
             srqmemx
01b4 245f                move.l   (sp)+,a2
01b6 4e75                rts

             *
             * DoIOQ(process_id)
             *
             DoIOQ:
01b8=4e40                os9      F$IOQu
01bc 2001                move.l   d1,d0          return code
01be 4e75                rts

             *
             * DoSRtMem(ptr, size)
             *
             DoSRtMem:
01c0 2f0a                move.l   a2,-(sp)
01c2 2440                move.l   d0,a2
01c4 2001                move.l   d1,d0
01c6=4e40                os9      F$SRtMem
01ca 245f                move.l   (sp)+,a2
01cc 4e75                rts
000001ce                 ends
```

The special CStart for file managers can be used for any file manager. There is no distinction between the different classes of file managers (RBF, SCF, etc.) or between one file manager and another within a class.

This version of CStart is much longer than it needs to be. It retains entirely separate code for each entry point. The refined CStart in appendix C acts like this one, but is substantially smaller.

27.3 The Dummy File Manager

Most entries into a file manager are straightforward. IOMan finds the path descriptor for the call, assembles the parameters for the call, and jsr's to the required entry in the file manager. In detail:

- IOMan finds the path descriptor for the given path number.
- It organizes contention for the path descriptor. If the path is already busy (consider duped paths), IOMan causes the current request to wait in the I/O Queue.

† *CStart*: see page 519

- It sets the PD_CPR and PD_LProc fields to the current user ID.
- It calls the correct entry in the file manager.
- When the file manager returns, IOMan checks the I/O queue. If there are any processes waiting on the I/O queue, IOMan removes a process from the queue and signals it to wakeup.

This is IOMan's action for Delete, Seek, Read, Write, ReadLn, and WriteLn. IOMan takes a more active role in processing the other functions.

27.3.1 Preprocessor Includes and Defines

The file manager uses the OS-9 error codes from errno.h, and the process descriptor structure given in the procid.h include file.

```
/* A dummy file manager for an RBF-type file */
#include <errno.h>
#include <procid.h>
typedef char *POINTER;
#include "format.h"
#include "PathDesc.h"
#define SECTORSIZE 512
```

27.3.2 Open

Before calling the Open entry in the file manager, IOMan creates and initializes a path descriptor. In detail:

1. It finds a free path descriptor and a free path number for the process.
2. It sets the PD_COUNT and PD_CNT fields to 1.
3. It sets PD_MOD to the access mode passed with the `I$Open` SVC.
4. It initializes PD_USER to the current user.
5. If the device is non-sharable and already opened on some path, IOMan returns an error.
6. If the device is not initialized, IOMan attaches it.
7. It copies the options from the device descriptor into the path descriptor.
8. It sets PD_DEV to point to the device's device table entry.

9. IOMan maintains a linked list of open paths for each device. The linked list starts at V_Paths in device static storage and ends with a NULL. The links are through the PD_Paths field in the path descriptors.

The remainder of the path descriptor is filled with zeroes.

The file manager may use the variables set by IOMan, but it should not change them.

A file manager that will use RBF device drivers must do some setup activity to keep the driver happy. This function duplicates PD_DEV into PD_DVT and sets PD_FD to 0 (there is no FD sector). It also sets PD_DTB to point to the correct drive table entry.

The Open function also sets some variables that will be used in the file manager. It allocates an I/O buffer and points PD_BUF at the buffer, sets PD_CP (current position) to 0, and indicates that there is no sector in the I/O buffer by claiming that sector −1 is buffered.

Since this file manager will read PC-DOS disks, it is constantly fighting the device driver's updates to the drive table. The device driver is normally responsible for the drive table. It maintains this table by copying a portion of sector 0 into the drive table every time it reads it. This works fine when the disk is in OS-9 format. A file manager that managed OS-9-format disks could read sector zero and trust the device driver to update the drive table. The first sector on a PC-DOS disk certainly does not contain information in OS-9 system sector format. This file manager must read sector zero then shuffle data around to convert PC-DOS system information into a pseudo OS-9 system sector.

The open function should copy the file name into the path descriptor if file names have any meaning.

```
Open(pd, regs, procd, SysGlobs)
register PD_TYPE pd;
{
   register PD_OPTS OptionPtr;
   int RVal;


   /*
         Initialize the path descriptor.
   */
   if((pd->PD_BUF = (char *)_srqmem(SECTORSIZE)) == (char *)-1)
      return E_MEMFUL;

   OptionPtr = (PD_OPTS)(&pd->PD_OPT);
   OptionPtr->PD_DVT = (POINTER)pd->PD_DEV;
```

```
    OptionPtr→PD_FD = 0;

    pd→PD_DTB = (POINTER)&pd→PD_DEV→V_STAT→
            V_DRIVES[OptionPtr→PD_DRV];
    pd→PD_CP = 0;                     /* current offset in file          */
    pd→PD_CSector = −1;               /* no sector in buffer             */

    if((RVal = ReadSector(pd, 0, pd→PD_BUF, regs, procd, SysGlobs)) == 0)
        InitFromBoot(pd, pd→PD_BUF);

    return RVal;
}
```

Properly, the open function should have called the open setstat in the device driver before returning.

27.3.3 Seek

IOMan takes no interest in `I$Seek`. It finds the path descriptor and passes the call to the file manager.

```
Seek(pd, regs, procd, SysGlobs)
register PD_TYPE pd;
register REGS regs;
{
    pd→PD_CP = regs→R_d1;
    return 0;
}
```

27.3.4 Read

This is another call that IOMan largely ignores. IOMan checks for possible security violations, finds the right path descriptor and calls the file manager. The file manager is responsible for deciding which sector(s) on the disk contains the data at the position specified in the path descriptor, reading the sector from the disk, and copying the required data into the user's buffer.

File locking should be done in this function. This is also one of the places where cleverness about letting the device driver move data directly into the user's buffer would be hidden.

```
Read(pd, regs, procd, SysGlobs)
register PD_TYPE pd;
```

```
REGS regs;
{
    unsigned long length, i;
    register char *dest, *ptr;
    int ReturnVal=0;
    unsigned long Sector, offset;

    Sector = pd→PD_CP >>9;                    /* divide current position by 512          */
    offset = pd→PD_CP & (SECTORSIZE −1);
    length = regs→R_d1;
    dest = regs→R_a0;

    while(length > 0){
        if(pd→PD_CSector != Sector)
            ReturnVal = ReadSector(pd, Sector, pd→PD_BUF,
                regs, procd, SysGlobs);
            if(Sector == 0 && ReturnVal == 0 )
                    InitFromBoot(pd, pd→PD_BUF);
            if(ReturnVal != 0)
                break;
        }else
            ReturnVal = 0;

        /*
            At least part of this sector should be copied to the caller's buffer. The "interesting"
            data starts at offset from the beginning of the sector and continues for length
            bytes, or to the end of the sector (whichever is least).
        */
        i = SECTORSIZE − offset;
        if(i>length)
            i = length;
        length −= i;

        pd→PD_CP += i;                          /* Update current position in pd          */

        /* Copy the data to the caller's buffer */
        for(ptr = pd→PD_BUF+offset;i>0; i−−) *dest++ = *ptr++;

        /* Now prepare to read the next sector */
        ++Sector;
        offset = 0;
    }
    return ReturnVal;
}
```

27.3.5 Close

IOMan takes an interest in the I$Close SVC. Before it calls the file manager, IOMan decrements PD_COUNT. If the path isn't busy, IOMan calls the Close entry in the file manager. If the path has no remaining users, IOMan frees the path descriptor. If the device is now unused, IOMan detaches the device.

The file manager must free any memory it allocated at open if the path is unused (PD_COUNT of zero). IOMan is about to free the path descriptor and the file managers will never see it again.

If file management requires any action when a file is closed, such as flushing write buffers, this is the place to do it.

```
Close(pd, regs, procd, SysGlobs)
register PD_TYPE pd;
{
    if(pd→PD_CNT == 0)              /* Is this path unused?                 */
       if(pd→PD_BUF != 0){          /* Is there a buffer for this path?     */
          DoSRtMem(pd→PD_BUF, SECTORSIZE);          /*Free the buffer mem */
          pd→PD_BUF = 0;
       }
    return 0;
}
```

27.3.6 MakDir

IOMan does a great deal to help the file manager with the I$MkDir SVC. It creates and initializes a path descriptor as if this were an I$Open SVC. After calling the file manager's MakDir function, IOMan removes the path descriptor exactly as if it had returned from the file manager's Close function.

MakDir in IOMan is essentially a duplicate of Open processing up to the call to the file manager. After its call to the file manager's MakDir function, IOMan follows the same procedure it uses after calling the file manager's close function. The only difference is that MakDir knows the path descriptor doesn't have multiple users.

This file manager doesn't implement MakDir, but you can find an example in the PC-DOS file manager.

```
MakDir(pd, regs, procd, SysGlobs)
{
    return 0;
}
```

27.3.7 Create

From IOMan's point of view, the only difference between opening a path and creating a file is the entry in the file manager that it calls.

Inside the file manager the functions are usually similar. Often the create function is aliased to the open function. In any case, a file manager should perform the same path descriptor initialization as open.

```
Create(pd, regs, procd, SysGlobs)
{
    return 0;
}
```

27.3.8 ChdDir

The default directories are attributes of a process, not a path. As it does for MakDir, IOMan creates a temporary path for ChdDir.

IOMan will record the device that contains the default directory. The file manager must store enough information for it to find the directory on the device. It should store this information in the current process descriptor. The _dio area in the process descriptor may be used to store default directory information. This area holds information about both the default data directory and the default execution directory. The first 12 bytes are for the data directory, the next 12 for the execution directory.

IOMan puts a pointer to the device table entry for the directory in the first long word of each directory specification. The rest is for the file manager's use.

See the PC-DOS file manager for an example of ChdDir and the code in Open that respects the default directories.

```
ChdDir(pd, regs, procd, SysGlobs)
{
    return 0;
}
```

27.3.9 Delete

At the SVC level, file deletion operates on a file name, not a path descriptor. This function is another one that works almost like MakDir (which, in turn, is much like Open). It creates a temporary path descriptor for the call, calls the file manager with the temporary descriptor, then disposes of the descriptor.

In the file manager the Delete function should start by opening the file or some very similar operation, and finish by closing the path.

See the PC-DOS example for a working Delete function.

```
Delete(pd, regs, procd, SysGlobs)
{
    return 0;
}
```

27.3.10 Write

IOMan only takes its minimum actions for writes. For a file manager, writing is like reading.

```
Write(pd, regs, procd, SysGlobs)
{
    return 0;
}
```

27.3.11 ReadLn and WriteLn

IOMan doesn't distinguish between read and readln or write and writeln. For the file manager as well, readln is very similar to read. One interesting option is to consider different line ending strategies. For instance, a line does not neccessarily end with a byte value. Lines could *start* with a count. ReadLn and WriteLn would be a clean interface to a message passing system.

```
ReadLn(pd, regs, procd, SysGlobs)
register REGS regs;
{
    return 0;
}


WriteLn(pd, regs, procd, SysGlobs)
{
    return 0;
}
```

27.3.12 GetStat and SetStat

IOMan handles some status functions: set and get options, and read device name. All setstat and getstat functions are passed to the file manager even when IOMan seems to have done what's required. This proves to be a good policy. If you look at the SCF device driver you will see that IOMan passes set option setstats to the file manager who passes them on to the device driver. The device driver adjusts the hardware options to fit the path options.

```
GetStat(pd, regs, procd, SysGlobs)
{
    register STATICSTORETYPE DevStatic;

    DevStatic = pd→PD_DEV→V_STAT;

    /* Do things that don't require the device driver */
    /* ...and return ...or ... */
    /* Wait for the device to be idle */
    while(DevStatic→V_BUSY) DoIOQ(DevStatic→V_BUSY);
    DevStatic→V_BUSY = pd→PD_CPR;

    /* Call the device driver */

    DevStatic→V_BUSY = 0;                /* device not busy                 */
    return 0;
}


SetStat(pd, regs, procd, SysGlobs)
{
    register STATICSTORETYPE DevStatic;

    DevStatic = pd→PD_DEV→V_STAT;

    /* Do things that don't require the device driver */
    /* ...and return ...or ... */
    /* Wait for the device to be idle */
    while(DevStatic→V_BUSY) DoIOQ(DevStatic→V_BUSY);
    DevStatic→V_BUSY = pd→PD_CPR;

    /* Call the device driver */

    DevStatic→V_BUSY = 0;                /* device not busy                 */
    return 0;
}
```

27.3.13 Support Functions

This is the function that contains the high-level interface to the device driver.

```
ReadSector(pd, Sector, buffer, regs, procd, SysGlobs)
register PD_TYPE pd;
int Sector;
char *buffer;
{
    int ReturnVal;
    char *HoldBuffer;
    register STATICSTORETYPE DevStatic;

    DevStatic = pd→PD_DEV→V_STAT;

    /* Wait for the device to be idle */
    while(DevStatic→V_BUSY) DoIOQ(DevStatic→V_BUSY);
    DevStatic→V_BUSY = pd→PD_CPR;

    /*The supplied buffer might not be the one in the path descriptor */
    HoldBuffer = pd→PD_BUF;
    pd→PD_BUF = buffer;

    /*Call the device driver to read a sector */
    ReturnVal = CallRead(1,                /* contig sectors           */
        Sector,                            /* sector number            */
        pd,
        DevStatic,                         /* device static storage    */
        procd,
        regs,
        SysGlobs);

    DevStatic→V_BUSY = 0;                  /* device not busy          */

    /* Deal with a strangeness of the driver */
    if(Sector == 0 && ReturnVal == E_BTYP)
        ReturnVal = 0;

    /* Update the Current Sector field in the path descriptor */
    if(ReturnVal == 0)
        pd→PD_CSector = Sector;
    else
        pd→PD_CSector = −1;
    return ReturnVal;
}
```

The following function is responsible for setting values in the drive table.

```
static InitDriveTable(pd, FATStart, FATCopies, DirSize, ClusterSize,
        FATSize, TrackSize, Sides, Size)
register PD_TYPE pd;
{
    register DriveTableType *DriveTable;

    DriveTable = (DriveTableType *)pd→PD_DTB;
    DriveTable→DD_TOT[0] = (Size >> 16) & 0x00ff;
    DriveTable→DD_TOT[1] = (Size >> 8) & 0x00ff;
    DriveTable→DD_TOT[2] = Size & 0x00ff;
    DriveTable→DD_TKS = DriveTable→DD_SPT[1] = TrackSize & 0x00ff;
    DriveTable→DD_SPT[0] = (TrackSize >> 8) & 0x00ff;
    DriveTable→DD_FMT =
        ((Sides == 2) ? 1 : 0) +              /* 1: double sided           */
        2 +                                   /* 2: always double density  */
        ((Size > 720) ? 4 : 0);               /* 4: 80 track               */
    DriveTable→V_FATSz = FATSize;
    DriveTable→DD_DIR = FATStart + (FATSize * FATCopies);
    DriveTable→DD_FirstFAT = FATStart;
    DriveTable→DD_FATCnt = FATCopies;
    DriveTable→V_DirEntries = DirSize;
    DriveTable→DD_FATSIZ = FATSize;
    return;
}
```

The following function picks useful information out of the PC-DOS boot sector and converts it into values that OS-9 needs:

```
static InitFromBoot(pd, BootPtr)
PD_TYPE pd;
BootSectorType BootPtr;
{
    InitDriveTable(pd,
        2,                                    /* Start of FAT              */
        BootPtr→FATCopies,
        (BootPtr→RootDirSize[1] << 8) + BootPtr→RootDirSize[0],
        BootPtr→SectorsPerCluster,
        (BootPtr→SectorsPerFAT[1] << 8) + BootPtr→SectorsPerFAT[0],
        (BootPtr→SectorsPerTrack[1] << 8) + BootPtr→SectorsPerTrack[0],
        (BootPtr→Sides[1] << 8) + BootPtr→Sides[0],
        (BootPtr→TotSectors[1] << 8) + BootPtr→TotSectors[0]);
        return;
}
```

27.3.14 The Format.h Header File

```
#define BOOTSECTOR 0
#define FATSTART 1
#define FILERASED '\0xE5'
#define DEFAULT_DRIVES 2

        /* Attributes */
#define MS_READ_ONLY 0x1
#define MS_HIDDEN 0x2
#define MS_SYSTEM 0x4
#define MS_V_LABEL 0x8
#define MS_SUBDIR 0x10
#define MS_ARCHIVE 0x20

typedef unsigned char uchar;
typedef unsigned long ulong;

 typedef struct {
    char Reserved1[3];              /*A branch instruction               */
    char SystemID[8];
    uchar SectorSize[2];            /*Bytes per sector                   */
    uchar SectorsPerCluster;
    uchar ReservedSectors[2];       /*Number of reserved sectors at start */
    uchar FATCopies;
    uchar RootDirSize[2];           /*Number of entries in root directory */
    uchar TotSectors[2];            /*Sectors on the disk                */
    uchar FormatID;                 /*F8..FF                             */
    uchar SectorsPerFAT[2];
    uchar SectorsPerTrack[2];
    uchar Sides[2];
    uchar S_ReservedSectors[2];     /*Special reserved sectors           */
}*BootSectorType;

 typedef struct {
    char FileName[8];
    char FileExtension[3];
    uchar FileAttr;
    char Reserved[10];
    uchar Time[2];
    uchar Date[2];
    uchar StartCluster[2];
    uchar FileSize[4];
}*MSDirE;
```

```
/* File attributes */
#define VOL_LABEL 0x20
#define SUB_DIRECTORY 0x10
#define READ_ONLY 0x08
#define MODIFIED 0x04
#define HIDDEN 0x02
#define SYSTEM_FILE 0x01

typedef uchar SmallFAT_Entrys[3];


typedef struct {
    long R_d0, R_d1, R_d2, R_d3, R_d4, R_d5, R_d6, R_d7;
    char *R_a0, *R_a1, *R_a2, *R_a3, *R_a4, *R_a5, *R_a6, *R_a7;
    uchar R_ssr;                    /*Status register – system part              */
    uchar R_cc;                     /*Status register – condition code part      */
    short *R_pc;                    /*Program counter register                   */
    short R_fmt;                    /*68010 exception format and vector          */
}*REGS;

typedef struct {
    uchar      DD_TOT[3];           /*Total number of sectors on device          */
    uchar      DD_TKS;              /*Track size in sectors                      */
    ushort     DD_FATSIZ;           /*Number of bytes in FAT                     */
    ushort     DD_SPC;              /*Number of sectors per cluster              */
    ushort     DD_DIR;              /*Address of root directory                  */
                                    /*The address is actually an lsn: 24 bits    */
                                    /*but since it is always around 16,          */
                                    /*16 bits more than suffice                  */
    ushort     DD_OWN;              /*Owner ID (meaningless)                     */
    ushort     DD_DSK;              /*Disk ID                                    */
    ushort     DD_ATT;              /*Attributes, one extra byte to compensate for */
                                    /*DD_DIR (which was short)                   */
    uchar      DD_FMT;              /*Disk format; density/sides                 */
    uchar      DD_SPT[2];           /*Sectors per track                          */
    uchar      DD_FATCnt;           /*Copies of FAT                              */
    uchar      DD_FirstFAT;         /*First FAT Sector                           */
    uchar      DD_Reserved;         /*Pad to an even boundary                    */
    ushort     V_TRAK;              /*Current track                              */
    POINTER V_FileHd;               /*Open file list for this drive              */
    ushort     V_DiskID;            /*Disk ID (duplicate of DD_DSK?)             */
    ushort     V_FATSz;             /*FAT size                                   */
    ushort     V_FATSct;            /*Lowest FAT word to search                  */
    ushort     V_FATB;              /*FAT busy flag                              */
    POINTER V_ScZero;               /*Pointer to sector zero buffer              */
    uchar     V_ZeroRd;               /*Sector zero read flag                    */
    uchar     V_Init;                 /*Drive initialized flag                   */
    ushort    V_ResBit;               /*Reserved bitmap sector number (if any)   */
    ulong     V_SoftEr;
    ulong     V_HardEr;
    ushort    V_DirEntries;
    ulong     V_Reserved[8];
}DriveTableType;

        /*I/O Device Static storage required by the kernel for all device types.  */
typedef struct {
    POINTER   V_PORT;                 /*Device base port address                 */
    ushort    V_LPRC;                 /*Last active process ID                   */
    ushort    V_BUSY;                 /*Current process ID (0=idle)              */
    ushort    V_WAKE;                 /*Active process ID if driver must wakeup  */
    POINTER   V_Paths;                /*Linked list of open paths on device      */
    ulong     V_Reserved[8];
                                      /*Static storage for RBF drivers           */
    uchar     V_NDRV;                 /*Number of drives                         */
    uchar     V_DReserved[7];
    DriveTableType V_DRIVES[DEFAULT_DRIVES];
                                     /* This may be the wrong size but that's ok */
                                      /*Followed by device driver static storage */
}*STATICSTORETYPE;
```

27.3.15 The Special PathDesc.h Header File

```
typedef struct PDTYPE {
    unsigned short  PD_PD;            /*Path number                              */
    unsigned char   PD_MOD;           /*Mode (read/write/update)                 */
    unsigned char   PD_CNT;           /*Number of open images                    */
    struct DEVTAB *PD_DEV;            /*Device table entry address               */
    unsigned short  PD_CPR;           /*Current process ID                       */
    POINTER         PD_RGS;           /*Caller's register stack pointer          */
    char            *PD_BUF;          /*Buffer address                           */
    unsigned int    PD_USER;          /*User ID of path's creator                */
    struct PDTYPE *PD_Paths;          /*Linked list of open paths on device      */
    unsigned short  PD_COUNT;         /*Actual number of open images             */
    unsigned short  PD_LProc;         /*Last active process ID                   */
    short     PD_Reserved[6];
    /*
        File manager storage
    */
    unsigned char   PD_SMF;           /*State flags                              */
    unsigned char   PD_Unused[3];
    unsigned long   PD_CSector;         /*Number of sector in the buffer           */
    unsigned long   PD_CP;              /*Current logical byte position            */
    unsigned long   PD_SIZ;             /*File size                                */
    short           PD_Unused1[7];      /*To put PD_DTB in the right spot          */
    POINTER         PD_DTB;             /*Drive table pointer                      */
    /*
        The fields so far add up to 34 bytes of file manager storage.
        86 bytes are required to bring us up to the option area.
    */
    char        PD_Unused2[86];
    char        PD_OPT;                   /*Dummy field to signify the beginning of
                                            the options section                    */
    /* additional fields go here */
}*PD_TYPE;

typedef struct {
    unsigned char   PD_DTP;             /*Device type                              */
    unsigned char   PD_DRV;             /*Drive number                             */
    unsigned char   PD_STP;             /*Step rate                                */
    unsigned char   PD_TYP;             /*Disk device type                         */
    unsigned char   PD_DNS;             /*Density capability                       */
    unsigned char   PD_reserved2;
    unsigned short  PD_CYL;             /*Number of cylinders                      */
    unsigned char   PD_SID;             /*Number of sides                          */
    unsigned char   PD_VFY;             /*0=verify disk writes                     */
    unsigned short  PD_SCT;             /*Default sectors per track                */
    unsigned short  PD_TOS;             /*Default sectors per track (tr0, s0)      */
    unsigned short  PD_SAS;             /*Segment allocation size                  */
    unsigned char   PD_ILV;             /*Sector interleave offset                 */
    unsigned char   PD_TFM;             /*DMA transfer mode                        */
    unsigned char   PD_TOffs;           /*Track base offset                        */
    unsigned char   PD_SOffs;           /*Sector base offset                       */
    unsigned short  PD_SSize;           /*Size of sector in bytes                  */
    unsigned short  PD_Cntl;            /*Control word                             */
    unsigned char   PD_Trys;            /*Number of tries (1=no error correction)  */
    unsigned char   PD_LUN;             /*SCSI unit number of drive                */
    unsigned short  PD_WPC;             /*First cylinder using write precomp       */
    unsigned short  PD_RWC;             /*First cylinder using reduced write current */
    unsigned short  PD_Park;            /*Park cylinder for hard disks             */
    unsigned long   PD_LSNOffs;         /*Logical sector number offset for partition */
    unsigned short  PD_TotCyls;         /*Total number of cylinders on device      */
    unsigned char   PD_CtrlrID;         /*SCSI controller ID                       */
    unsigned char   PD_reserved3[14];
    unsigned char   PD_ATT;             /*File attributes                          */
    unsigned long   PD_FD;              /*File descriptor psn                        */
    unsigned long   PD_DFD;             /*Directory file descriptor psn              */
    unsigned long   PD_DCP;             /*Directory entry pointer                    */
    POINTER         PD_DVT;             /*Device table pointer (copy)                */
    unsigned char   PD_reserved4[26];
    char            PD_Name[32];        /*Filename                                   */
}*PD_OPTS;

typedef struct DEVTAB {
    POINTER V_DRIV;
    STATICSTORETYPE V_STAT;
    POINTER V_DESC;
    POINTER V_FMGR;
    short V_USRS;
}*DEVTABTYPE;
```

Chapter 28

Adding a New Device Driver

This chapter discusses the reason for device drivers, then moves on to reasons for creating new drivers. The actual business of writing a driver is left for chapters 29 and 30, and appendix D.

Device drivers are operating system modules that deal with the actual hardware of an I/O device. Other parts of OS-9 deal with an idealized device. All SCF devices seem to perform the same operations in the same way from the point of view of every module except the device driver. The driver does whatever is necessary to make the real device look like the imaginary device that the rest of the OS-9 world sees.

This philosophy has some important implications. It gives OS-9 tremendous flexibility. Only one module has to be written to permit the system to use a new device. The only limit on the number of device drivers that OS-9 can support concurrently is the memory that they all take. Eventually, the drivers and their associated buffers and descriptors will use up more memory than you can tolerate. Since drivers usually need only a little memory this is seldom an important limit.

There is a hidden cost for this flexibility. When you know the characteristics of the device you are working with there is a lot you can do to optimize your system. Isolating that knowledge in device drivers prevents the rest of the system from taking advantage of any special features a device might have.

On a system with memory-mapped video, positioning the cursor is a trivial operation. The screen is mapped into a block of memory; the cursor position is just an address. On a system with a terminal, positioning a cursor is a harder task. OS-9 doesn't concern itself with cursor positioning, not because it isn't important, but because a system general enough to work on systems with very "dumb" terminals would be wasteful on systems with memory-mapped video.

Cursor positioning[1] is an example of a device characteristic that OS-9 hasn't taken responsibility for, but there are other things like buffering and error handling that OS-9 hides in the device driver at some cost in speed and power. Terminal characteristics are left to programs and library routines.

The actual design of a device driver is taken up in chapters 29 and 30, and appendix D. It isn't difficult, but must be done carefully. ***Sysdbg, ROMBug,*** and the ROM debugger work on system code, but many problems at the operating system level involve timing or unexpected dependencies. A defective driver for a serial port could easily only manifest its problem when it's running full tilt in a heavily loaded system. Any bugs you write into the driver tend to have hair and teeth!

28.1 Why Create New Drivers?

If you like to play with your operating system, device drivers are a good playground. The operating system is meant to be expanded by having drivers added to it, and there are many opportunities for expansion.

If this kind of thing excites you, study the drivers presented here, and customize your own. Two warnings:

- OS-9 is an evolving operating system. New features are the visible sign of evolution, but many changes only improve performance, fix bugs, or add support for new processors. Compatibility with old user-state code is almost an absolute rule at Microware. Compatibility with old system-state code is only an important goal.

  Microware considers device drivers part of the operating system. If they find compelling reasons to drop compatibility with their old drivers, they will.[2] However, Microware tries (maybe tries too hard) to remain compatible with old system code. OS-9's evolution is unlikely to break your drivers if you follow the design of Microware's drivers as closely as possible and stick carefully to documented interfaces.

- Make a special effort to keep the program interface of your driver compatible with Microware's distributed drivers. If you add enhancements that make you slightly incompatible, you may find that a program you buy relies on the feature you changed.

Device drivers are a particularly important part of a real-time control system. Not only do real-time systems sometimes have special devices to support, but device drivers

[1] The C termcap library supports almost any terminal with a termcap database and a set of C functions.

[2] I don't remember any OS-9/68000 changes that lost compatibility with well-behaved old drivers. The compat bytes in the init module support old behavior.

are entered only a few cycles after an interrupt takes place. If you need to respond to an interrupt with some almost-instant action, the interrupt service routine of a device driver is the only place to do the processing. Normal processes are run and put to sleep at the whim of the dispatcher; interrupt service routines run as soon as the source of the interrupt is discovered.

If, for example, you are controlling an outgoing voltage based on an incoming voltage, the times required for A/D (Analog-to-Digital) and D/A (Digital-to-Analog conversion) may be almost more than you can afford. A device driver could be designed to drive both devices and perform some simple computations. It would pass information on to a normal program for low-priority processing, but would respond almost instantly to each interrupt.

If you create a new device driver with a new name, you must also build a device descriptor for it. No device can be used without a descriptor.

If you build or buy a new device driver, you may not want to install it in your boot file immediately. If you want to experiment first, or don't want to use space in the boot for a seldom-used device, device drivers can be loaded after the system is booted. Just make sure that both the device driver and the device descriptor stay linked as long as they are being used.

One good cause for inexplicable errors is that the driver has come unlinked and disappeared from memory. If this happens, unlink the descriptor and load and link both the descriptor and the driver again. Since modules in the bootstrap can't be dropped from memory no matter how many times they are unlinked, the problem doesn't show up with modules from OS9Boot. If you load parts of your I/O system after the system is booted, be careful.

Chapter 29

Sample SCF Device Driver

This chapter contains a complete device driver for the Motorola 68681 I/O device. It includes most of the common features of SCF device drivers.

The device driver in this chapter is Microware's standard 68681 device driver for OS-9/68000 version 2.1 updated to version 3.0 standards.[1] The version is important. Device drivers are parts of the operating system and the requirements they must meet change as OS-9 evolves. This driver is very likely to work with future versions of OS-9/68000, but it may require adjustments as OS-9 changes.

29.1 Module Header

A device driver should have a module type of Drivr and the ReEnt[2] and SupStat attributes.

The stack size in the psect directive should be zero. This doesn't mean that the device driver is expected to run with no stack. It uses the system stack for the calling process (except for the IRQ routine). Although the driver may have more than a kilobyte available on the stack, it shouldn't count on more than about 256 bytes of stack space. The driver gets the stack after the kernel, IOMan, and the file manager have each consumed what they need.

```
Edition     equ     14                      current Edition number
```

[1] This driver is copyrighted ©1984 by Microware Systems Corporation and Reproduced Under License. This source code is the proprietary, confidential property of Microware Systems Corporation, and is provided to licensee solely for documentation and educational purposes. Reproduction, publication, or distribution in any form to any party other than the licensee is strictly prohibited.

[2] Reentrancy is not absolutely required for drivers, but it is strongly suggested. Since a non-reentrant driver will only accept one link, it can only be used for one device.

```
Typ_Lang set    (Drivr<<8)+Objct
Attr_Rev set    ((ReEnt+SupStat)<<8)+0
         psect  MzrMpsc,Typ_Lang,Attr_Rev,Edition,0,MpscEnt

         use    defsfile
```

Defsfile includes oskdefs.d and systype.d. Some of the values in oskdefs.d and systype.d are also in sys.l, but the linker has limited expression-handling facilities (for instance it cannot shift or complement values), and some important values are not in sys.l.

```
Typ_Lang set    (Drivr<<8)+Objct
```

The linker only knows how to substitute values at given offsets. It can't do arbitrary arithmetic.

29.2 Definitions

A device driver is a cryptic piece of code at best. It helps if the driver explains and names the "magic" constants for the driver and its I/O device.

```
No_IRQ   set    1                 (non-zero enables IRQ code)
Signbit  set    7
InpSiz   set    80                input buffer size
OutSiz   set    140               output buffer size
MinBuff  equ    10                send XON at MinBuff
MaxBuff  equ    InpSiz–MinBuff    send XOFF at MaxBuff
```

The read and write routines in an interrupt-driven device driver don't actually transfer data to or from the I/O hardware. In general, the IRQ routine manipulates the hardware and the read and write routines deal with I/O buffers. There is a grey area where buffer management involves interaction with the hardware.

The I/O buffers should be large enough to accommodate the next unit up from a character—generally, a line. If the output buffer is too small, processes find themselves blocked while the driver's IRQ routine works. This affects performance, but it isn't catastrophic. If the input buffer is too small, unneccessary flow control may be used. In the worst case input can be lost. When the input buffer is nearly full the driver will transmit an XOff character to the sender (if the device descriptor shows XOff support). If there is no flow control, the IRQ routine announces an error and starts dropping input.

A human at a keyboard is unlikely to overflow any buffer, but a 9600 baud modem or a terminal that can dump a buffer at 19.2 Kbaud will challenge a loaded system.

If you expect 2K screen dumps or 256 byte xmodem buffers, make the input buffer slightly larger than the expected input block. This will let the IRQ routine run at full speed into the buffer, and let the program read an entire block without waiting.

```
        ABbit     equ     4                bit #4 of port address tells the "side"
        BrkTime   equ     $80000000+128    break sent for 500mSec.
        RxDefault equ     RxRTS            RxRTS control enabled
        TxDefault equ     TxCTS            TxCTS control enabled
```

The RxDefault and TxDefault values are used in the RTSmode and TXmode fields in device static storage.

All the device control registers are addressed relative to the device address that will be specified in the device descriptor. If the relative addresses of the I/O registers in the device were not fixed by the I/O device, it would be better to define all the addresses in the descriptor.

```
********************
* Register offset definitions.
*

* these offsets are "side" offsets from "device side" address

        MPSMode equ     $00              68681 mode register
        MPSBdSt equ     $02              68681 baud rate/status register
        MPSCntl equ     $04              68681 control register
        MPSData equ     $06              68681 data register

* these offsets are "base" offsets from device "base" address

        MPSAcr    equ   $08              68681 ACR register
        MPSImr    equ   $0a              68681 interrupt mask/status register
        MPSVec    equ   $18              68681 interrupt vector register
        MPSOPCR   equ   $1a              68681 output port configuration reg.
        MPSOPSet  equ   $1c              68681 output port SET register
        MPSOPClr  equ   $1e              68681 output port CLEAR register
```

The following equates define the important values for each I/O register.

```
* MPSMode Register

        RxRTS     equ     %10000000      MR1 - rx rts flow control enable
        TxRTS     equ     %00100000      MR2 - tx rts flow control enable
        TxCTS     equ     %00010000      MR2 - tx cts flow control enable

* MPSAcr Register
```

```
DeltaMask equ      %00001111          delta IPx change mask
CTMask    equ      %01110000          counter/timer source bits
Set2      equ      %10000000          select baud set #2
Set1      equ      %00000000          select baud set #1
ACRDeflt  equ      Set2               default acr mode (w/o timer values)

* MPSBdSt Register

TxE_Bit   equ      2                  transmit RDY bit
RxA_Bit   equ      0                  receive char avail bit
IPOverrun equ      %00010000          input over-run status bit
InputErr  equ      $70                input error mask

* MPSCntl Register

RxEnabl   equ      $1                 enable receiver
RxDisabl  equ      $2                 disable receiver
TxEnabl   equ      $4                 enable xmit
TxDisabl  equ      $8                 disable xmit
RxReset   equ      $20                reset receiver
TxReset   equ      $30                reset transmitter
ErrorRst  equ      $40                error reset
BreakRst  equ      $50                break condition reset
StartBrk  equ      $60                start break
StopBrk   equ      $70                stop break

* MPSImr register

RxIRQEnA  equ      $2                 enable channel A receiver interrupt
TxIRQEnA  equ      $1                 enable channel A transmitter interrupt
RxIRQEnB  equ      $20                enable channel B receiver interrupt
TxIRQEnB  equ      $10                enable channel B transmitter interrupt
IRQP_BitA equ      $03                xmit & rec channel A interrupt mask
IRQP_BitB equ      $30                xmit & rec channel B interrupt mask
IRQ_RecA  equ      1                  channel A rec bit no
IRQ_RecB  equ      5                  channel B rec bit no

* MPSOPCR register

OPCRmode equ       %00000000 default o/p port control register mode

OP0       equ      1<<0               OP0 set/reset pattern
OP1       equ      1<<1               OP1
OP2       equ      1<<2               OP2
OP3       equ      1<<3               OP3
OP4       equ      1<<4               OP4
OP5       equ      1<<5               OP5
OP6       equ      1<<6               OP6
OP7       equ      1<<7               OP7
```

29.3 Static Storage

A device driver can use storage from four pools.

- The system stack. There may not be room on the stack for substantial data structures, and data stored on the stack is effectively erased every time the driver returns to its caller. Stack storage is, however, convenient and efficient.
- Path descriptors can be used to store device driver variables, but it's not generally a good idea. Path descriptors are for the use of IOMan and the file manager. It is, however, reasonable to read the path descriptor as needed. The path descriptor provides static storage that lasts while the I/O path is open. If a path is duped, the duplicate paths share a path descriptor,[3] but path descriptors generally correspond to a single path to a device. The device driver's storage in a path descriptor can be used to store values that should span calls to the driver.
- The device static storage is shared between IOMan, the file manager, and the device driver. It stores values that are specific to the device (as opposed to a path or the device driver). The device static storage area can be thought of as a writable extension to the device descriptor. It can be used to store values that don't apply to any particular path. The I/O buffers are good examples of data structures that are typically stored in the device static storage.
- The OEM global area is available to the entire operating system. It can be used to communicate between device drivers, or between drivers and other system modules such as the bootstrap, SysGo, the clock module, and custom SVCs. It should only be used as a last resort.

Many of the fields in static storage for this driver are for the I/O buffers. The other fields reflect the state of the device or are stored here because the device static storage is a good place to cache values.

```
**********
* Static storage offsets
*
          vsect
InFill    ds.l    1            input buffer next-in pointer
InEmpty   ds.l    1            input buffer next-out pointer
InEnd     ds.l    1            end of input buffer
OutFill   ds.l    1            output buffer next-in pointer
```

[3]Duping is a common practice for standard I/O paths.

Table 29.1: SC68681 Device Static Storage

Fields	Application
InFill InEmpty InEnd OutFill OutEmpty OutEnd InCount OutCount InpBuf OutBuf	I/O buffer fields
BaseAddr IRQMask ChanelNo Otpt_On Otpt_Off Globl	Static fields: set at initialization time and kept here to avoid repeated recalculation
BaudRate Parity InHalt OutHalt RTSmode RTSstate TXmode SigPrc DCDPrc	Dynamic fields: describe the state of the device

```
OutEmpty ds.l   1           output buffer next-out pointer
OutEnd   ds.l   1           output buffer end of buffer pointer
BaseAddr ds.l   1           base address of port

InCount  ds.w   1           # of chars in input buffer
OutCount ds.w   1           # of chars in output buffer
IRQMask  ds.w   1           interrupt mask word
Globl    ds.w   1           offset to global masks
SigPrc   ds.w   3 signal on data ready process (pid, signal, path)
DCDPrc   ds.w   3 signal for DCD transitions process (pid, signal, path)

ChanelNo ds.b   1           channel number 0 = A 1 = B
BaudRate ds.b   1           baud rate value
Parity   ds.b   1           current parity value
InHalt   ds.b   1 input halted flag (non-zero if XON has been Sent)
OutHalt  ds.b   1           output IRQ's disabled when non-Zero
Otpt_On  ds.b   1           value to enable acia output IRQs
Otpt_Off ds.b   1           value to disable acia output IRQs
RTSmode  ds.b   1           RxRTS handshake mode
RTSstate ds.b   1           RxRTS current state
TXmode   ds.b   1           Tx handshake mode
InpBuf   ds.b   InpSiz      input buffer
OutBuf   ds.b   OutSiz      output buffer
         ends
```

```
* OutHalt bit numbers (causes of disabled output IRQ)

H_XOFF   equ    0           V_XOFF received; awaiting V_XON
H_Empty  equ    1           output buffer is empty
```

29.4 The Entry Vector Table

The device descriptor module only has one code entry point in its module header, but it contains seven separate routines. The single entry point is used for seven routines by using the module entry offset value to indicate a vector table. File managers (and IOMan) that use SCF device drivers know the structure of this vector table and use it to reach each entry point.

```
MpscEnt  dc.w   Init
         dc.w   Read
         dc.w   Write
         dc.w   GetStat
         dc.w   PutStat
         dc.w   Term
         dc.w   0                 Exception handler entry (0=none)
```

29.5 Init Routine

The device driver's init entry is not called by a file manager. It is called directly from IOMan. The init routine initializes the static data structures associated with a device and sets up the hardware for subsequent I/O.

Only the init and term entries are passed a pointer to the device descriptor. Although other entries can discover the address of the device descriptor with some effort, the init routine takes every value the driver will use from the device descriptor and saves it in the device static storage. This is particularly important for values that will be used in the IRQ handler component of the driver. The IRQ handler only has the address of the static storage; it does not see a path descriptor.[4]

[4]It would be difficult for the kernel to decide which path gets each character of input when the interrupt is being dispatched. Consider, the kernel doesn't even know which driver will catch the interrupt much less whether it is input, output, or error. It won't be able to assign a path until it is fairly into the driver.

```
* Initialize (Terminal) MPSC
*
* Passed: (a1) = device descriptor address
*       (a2) = static storage address
*       (a4) = process descriptor ptr
*       (a6) = system global data ptr
*
* Returns: nothing
*
* Error Return: (cc) = carry set
*       d1.w = error code
*
* Destroys: (may destroy d0–d7, a0–a5)
*
```

Start by initializing the easy values in device static storage. Here the device is made idle with empty buffers. The code sets up data structures for the I/O buffers and calculates a value for IRQMask.

IRQMask is moved into the processor's SR register to mask interrupts when the driver must do an "atomic" operation.

```
     Init:
*              Output IRQ's disabled; buffer empty
               move.b  #(1<<H_Empty),OutHalt(a2)
               lea.l   InpBuf(a2),a0       init buffer pointers
               move.l  a0,InFill(a2)
               move.l  a0,InEmpty(a2)
               lea.l   InpSiz(a0),a0       figure size of buffer
               move.l  a0,InEnd(a2)        mark end of input buffer
               lea.l   OutBuf(a2),a0       point to start of output buffer
               move.l  a0,OutFill(a2)      init output buff pointers
               move.l  a0,OutEmpty(a2)
               lea.l   OutSiz(a0),a0       figure size of out buffer
               move.l  a0,OutEnd(a2)       mark end of output buffer
               move.b  M$IRQLvl(a1),d2     get irq level
               asl.w   #8,d2               shift into priority
               move.w  d2,IRQMask(a2)      save temporary value
               move.w  sr,d2               get a copy of the SR
               andi.w  #^0700,d2           clear the interrupt mask
               or.w    IRQMask(a2),d2      set new interrupt mask
               move.w  d2,IRQMask(a2)      save for future use
```

Now the driver reads the port address from the device static storage,[5] converts it to a base address, and saves it in device static storage. This device has two classes of

[5] The port address is copied from the device descriptor into device static storage by IOMan.

registers. Some registers control the chip as a whole. These registers are addressed with offsets from the device's base address. The 68681 has two "sides" that can handle separate streams of I/O. Each side has a separate set of registers which are addressed with offsets from V_PORT. The driver also calculates the channel number within the device. Bit 4 (ABit) in the port address specifies the channel. The channel is used to initialize the Otpt_On and Otpt_Off values. These are precalculated values that are stored in device control registers to turn output on and off. Each channel has its own codes.

At the end of this block of code, the ChanelNo field is 0 (A) or 1 (B), the Otpt_On and Otpt_Off fields are set correctly for the channel, and BaseAddr is set to the the actual base address of the device (after the channel is masked out).

```
        movea.l V_PORT(a2),a3      I/O port address
        move.l  a3,d0              save device absolute address
        clr.b   ChanelNo(a2)       assume channel A
* Set interrupt enable flags on channel A
        move.b  #RxIRQEnA!TxIRQEnA,Otpt_On(a2)
        move.b  #^TxIRQEnA,Otpt_Off(a2) set xmit int disable flag
        btst.l  #ABbit,d0          figure out which port 0 = A, 1 = B
        beq.s   Init20
        move.b  #1,ChanelNo(a2) set to B
* Set interrupt enable flags for channel B
        move.b  #RxIRQEnB!TxIRQEnB,Otpt_On(a2)
        move.b  #^TxIRQEnB,Otpt_Off(a2) set xmit int disable flag
Init20  andi.b  #$E1,d0            get base address of port
        movea.l d0,a5              move to address register
        move.l  d0,BaseAddr(a2)    save base address
```

The 68681 supports two serial lines and can serve as the system clock. Since the clock driver and two SCF devices share the same chip, they must communicate with one another. The problem is that device-control registers are often write-only. A read to the address does not return the value last written into the control register. Since the value written into a single control register affects the operation of the clock driver and the device driver, both drivers maintain a shadow copy of the register in OEM global storage.

A system might contain several 68681's. This is accommodated by keeping an array of shadow registers. Some space in the device static storage is saved by storing the offset of the shadow register from the system global storage instead of an absolute address for the shadow register. This code saves the offset value in the field named Globl.

```
        move.w  M$DevCon(a1),d0 get offset of global masks
        beq     BadMode10          ..return error if descriptor is not valid
        move.w  (a1,d0.w),d0       get offset to global pair for this device
        add.w   #D_Start,d0         calc entry of the pair in OEM_Globals
        move.w  d0,Globl(a2)        save it
```

Next, the driver registers the device in the system polling table. The base address of the device was left in register A5 earlier. This base address is used to get the device vector. If the device interrupt vector is uninitialized, the driver sets it to the value from the device descriptor. If the value is initialized, the driver checks it against the value in the descriptor and reports an error if they differ. It returns a bad mode error, but it really means that the device descriptor for this device, or for the other side of the chip is incorrect.

With the vector number in D0, the interrupt priority from the device descriptor in D1, the address of the IRQ service routine (included in the driver) in A0, the device static storage pointer in A2, and the port address of the device in A3, the driver issues the F$IRQ system call to register the interrupt service routine with the kernel.

The F$IRQ call must be done at the right time. It must be done before the driver does anything that might cause the device to generate an interrupt. Otherwise the device might assert an interrupt that the kernel will fail to dispatch. However, the device static storage must be initialized to a point where the interrupt service routine can run successfully before the service routine can be registered.

```
        move.b  MPSVec(a5),d0       read current device vector
        cmpi.b  #$0f,d0             is it uninitialized vector ?
        beq.s   Init40              ..yes; go write the register
        move.b  M$Vector(a1),d1     get descriptor's vector
        cmp.b   d1,d0               is the descriptor in error ?
        beq.s   Init45              ..no; continue
        bra     BadMode10           ..yes; return error for invalid descriptor

Init40  move.b  M$Vector(a1),d0     get descriptor's vector
        move.b  d0,MPSVec(a5)       setup IRQ vector in device
Init45  move.b  M$Prior(a1),d1      get priority
        lea.l   MPSCIRQ(pc),a0      address of interrupt service routine
        os9     F$IRQ               add to IRQ polling table
        bcs.s   InitExit            ..exit if error
```

Now that the device is registered with the kernel, the driver can start device configuration. The next block of code configures the device. It leaves the hardware initialized but disabled.

The sequence of operations is:

- Reset the chip.
- Set the baud rate from the value in the device descriptor.

- Set the parity, stop bits, and bits per byte from the device descriptor.

Since the device descriptor contains standard values for various baud rates and parity values, the device driver searches tables for the device parameters that correspond to the given characteristics. The baud rate and parity can be changed by setstat calls, so the code that actually determines and sets the configuration is encapsulated in separate routines.

```
          move.b  #RxDefault,RTSmode(a2) Set RxRTS h/w control
          beq.s   Init50              ..bra if no RTS to assert
          st.b    RTSstate(a2)        signal RTS to be asserted
Init50    move.b  #TxDefault,TXmode(a2) Set TxCTS h/w control
          move.b  #OPCRmode,MPSOPCR(a5) Set o/p port configuration
          bsr.s   InitSP              first init the 68681
          move.b  PD_BAU–PD_OPT+M$DTyp(a1),d0 Get baud rate
          bsr.s   BaudCalc            set baud rate
          bcs.s   InitExit            ..exit if error
* Get stop bits, bits per char and parity
          move.b  PD_PAR–PD_OPT+M$DTyp(a1),d0
          bsr     BitPar              set stop bits, parity, & bits per char
          bcs.s   InitExit            ..exit if error
```

At this point the device is configured but disabled. Enable the receiver. This involves an operation on the device control register and its shadow copy in the OEM global area. The transmitter will not be enabled until the write entry is called. At this point there is nothing in the output buffer. Operations on the control register and its shadow in the OEM globals should always be atomic. Serious (and mysterious) things can go wrong if several processes update the registers at roughly the same time. Updates to a register that are only one instruction long are inherently atomic. No update that involves both the control register and its shadow can be done in one instruction[6] so the chunk of code, a "critical section," protects itself by masking interrupts while it runs.

The instructions printed in capital letters are in the critical section.

```
move.w  sr,–(sp)            save irq status
move.w  IRQMask(a2),sr      mask interrupts
MOVE.B  #RxEnabl!TxEnabl,MPSCntl(a3) Enable xmit and rec.
MOVE.B  Otpt_On(a2),d3      get enable flag
MOVE.W  Globl(a2),d0        get offset to global
OR.B    d3,(a6,d0.w)        turn xmit and rec on
MOVE.B  Otpt_Off(a2),d3     get disable mask
AND.B   d3,(a6,d0.w)        turn xmit off
```

[6] A value could be moved from the shadow register into the control register, but that would be redundant. The shadow register is a copy of the control register.

[†] *Critical Section*: see page 245

```
            MOVE.B  (a6,d0.w),MPSImr(a5) put into register
            MOVE.W  (sp)+,sr
            moveq.l #0,d1                no errors
InitExit:   rts
```

The subroutine that resets the 68681 device also contains a critical section. This routine does not affect the shadow register. It simply resets the chip in four different ways.

```
********************
* InitSP: initialize receiver/transmitter to idle state
*
* Passed: (a3) = device port address
*
* Returns: nothing
*
InitSP:     move.w  sr,–(sp)             save irq status
            move.w  IRQMask(a2),sr       mask irqs
            MOVE.B  #RxReset,MPSCntl(a3) reset receiver
            MOVE.B  #TxReset,MPSCntl(a3) reset xmit
            MOVE.B  #ErrorRst,MPSCntl(a3) reset error status
            MOVE.B  #BreakRst,MPSCntl(a3) reset channel break interrupt.
            MOVE.W  (sp)+,sr             enable irqs
            rts
```

The BaudCalc subroutine is called from the init entry and the setstat entry. This code has three steps:

1. Use the baud rate table to find the 68681 code for the given baud rate.[7]
2. Store the code from the table into the MPSBdSt register. This is a one-instruction update. It doesn't need to have interrupts masked to be atomic. The table uses the code $ff to indicate that the device does not support the corresponding baud rate.
3. Use the control register to signal the device to set the baud rate. The operation on the control register is atomic, but the entire sequence including changes to the shadow register is a critical section. This step is protected by masking interrupts.

[7] OS-9/6809 kept device-dependent baud rate and protocol information in the device descriptor. The device driver could simply use the control bytes from the descriptor to initialize the device. This made the driver simpler, but it caused great difficulties for any software that needed to adjust the rate or protocol of a device. How was a terminal emulator program to know the code that would set each particular device to each baud rate? The current system forces the device driver to interpret a device-independent code into the appropriate action, but that is the proper job of a device driver. Now any piece of software can look at a path options section and determine the setup for that path.

The exact technique for baud rate adjustment is very hardware dependent. In this case the table contains codes that select one of two baud rate sets supported by the chip (baud-rate set two). The operation on the status register instructs the device to use the baud rate in set two.

```
********************
* BaudCalc: initialize baud rate of device
*
* Passed: d0.b = OS-9 baud rate code
*       (a2) = static storage ptr
*       (a3) = device port address
*       (a6) = system global data ptr
*
* Returns: nothing
*
* Error Return: (cc) = carry set
*       d1.w = error code
*
      BaudCalc: move.l  a0,-(sp)            save reg
                andi.w  #$00ff,d0           mask out all except baud rate
                cmpi.w  #MaxBaud,d0         legal baud rate ?
                bge.s   BadMode             ..no; return error
                lea.l   BaudTable(pcr),a0   get table address
                move.b  (a0,d0.w),d1        get baud rate value for chip
                cmpi.b  #$ff,d1             available baud rate ?
                beq.s   BadMode             ..exit if unsupported rate
                move.b  d1,MPSBdSt(a3)      set baud rate in device
                move.b  d0,BaudRate(a2)     save current rate
                move.w  Globl(a2),d0        get the global table entry ptr
                addq.w  #1,d0               acr image held in second byte
                move.w  sr,-(sp)            save irq masks (NOTE: carry is clear)
                move.w  IRQMask(a2),sr      mask interrupts
                MOVE.B  (a6,d0.w),d1        get the current acr image (if any)
                ANDI.B  #CTMask+DeltaMask,d1 keep the c/t, delta bits the same
                ORI.B   #ACRDeflt,d1        add in default baud set
                MOVE.B  d1,(a6,d0.w)        update image
                MOVE.L  BaseAddr(a2),a0     get device BASE address
                MOVE.B  d1,MPSAcr(a0)       update the hardware
                MOVE.W  (sp)+,sr            restore irqs
                movea.l (sp)+,a0            restore register
                rts                         return (carry clear)

* here if illegal or unsupported baud-rate

      BadMode   movea.l (sp)+,a0            restore a0

      BadMode10 move.w  #E$BMode,d1               get error code
                ori.b   #Carry,ccr          set the carry
                rts                         return
```

The baud-rate code is in the range 0–15 with each number specifying a particular rate (see *The OS-9 Technical Manual*). This table gives the 68681 code for each of those rates.

```
* Baud rate table for Set 2 of MC68681:

        BaudTable
0194 ff         dc.b    $ff             0 – 50 baud unavailable
0195 00         dc.b    $00             1 – 75 baud
0196 11         dc.b    $11             2 – 110 baud
0197 22         dc.b    $22             3 – 134.5 baud
0198 33         dc.b    $33             4 – 150 baud
0199 44         dc.b    $44             5 – 300 baud
019a 55         dc.b    $55             6 – 600 baud
019b 66         dc.b    $66             7 – 1200 baud
019c aa         dc.b    $aa             8 – 1800 baud
019d 77         dc.b    $77             9 – 2000 baud
019e 88         dc.b    $88             A – 2400 baud
019f ff         dc.b    $ff             B – 3600 baud unavailable
01a0 99         dc.b    $99             C – 4800 baud
01a1 ff         dc.b    $ff             D – 7200 baud unavailable
01a2 bb         dc.b    $bb             E – 9600 baud
01a3 cc         dc.b    $cc             F – 19.2k baud

        MaxBaud equ     *–BaudTable
```

The following routine sets the number of bits per character, the number of stop bits and the parity mode. It is called from the Init entry and from the SetOpt setstat. This routine works like BaudCalc. The outline of its algorithm is:

- Isolate the parity code from D0.
- Find the parity in the parity table and retain the code for later use.
- Isolate the bits-per-character.
- Find the bits-per-character in the BC table (see page 408) and combine the code with the parity code. Retain the result for later use.
- Isolate the stop bit value.
- Find the stop bit code in the SB table (see page 408) and retain it for later use.

The parity and bit codes have been decoded with interrupts enabled. They must, however, be disabled before the device state is changed. This is not a one-instruction update. The sequence for the actual update is:

- Save the value of the status register.
- Mask interrupts.
- Update the device MPSMode register.
- Save the device state in device static storage.
- Restore the processor's status register (which restores the interrupt mask to its value before this routine masked interrupts).

```
******************************
* BitPar: set bits/character, # stop bits, parity mode
*
* Passed: d0.b = device configuration
*       bits 1,0: 0 = no parity
*                 1 = odd parity
*                 3 = even parity
*       bits 3,2: 0 = 8 bit data
*                 1 = 7 bit data
*                 2 = 6 bit data
*                 3 = 5 bit data
*       bits 5,4: 0 = 1 stop bit
*                 1 = 1.5 stop bits
*                 2 = 2 stop bits
*       (a2) = static storage pointer
*       (a3) = device port address
*
* Returns: nothing
*
* Error Return: (cc) = carry set
*       d1.w = error code
*
        BitPar:  move.l  a0,–(sp)          save register
                 moveq.l #0,d2             sweep d2
                 andi.w  #$00ff,d0         clear high end of word
                 move.w  d0,d1             copy parity value
                 andi.w  #3,d1             isolate parity code
                 lea.l   TabPar(pc),a0     point at parity mode table
                 move.b  (a0,d1.w),d2      get parity code
                 bmi.s   BadMode           ..exit if illegal value
                 move.w  d0,d1             get data bit size
                 lsr.w   #2,d1             make index value
                 andi.w  #3,d1             make legal index
                 lea.l   TabBC(pc),a0      point at bits/char table
                 or.b    (a0,d1.w),d2      add in bits/char
                 move.w  d0,d1             get stop bit value
                 lsr.w   #4,d1             make index value
                 andi.w  #3,d1             make legal index
```

```
                lea.l    TabSB(pc),a0       point at stop bit table
                move.b   (a0,d1.w),d3       get stop bit value
                bmi.s    BadMode            ..exit if illegal value
                move.w   sr,-(sp)           save irq masks (NOTE: carry is clear)
                move.w   IRQMask(a2),sr     mask interrupts
                MOVE.B   #$10,MPSCntl(a3)   point to mode 1 register
                OR.B     RTSmode(a2),d2     add RxRTS h/w handshake mode
                MOVE.B   d2,MPSMode(a3)     set parity/bit per char/RxRTS control
                OR.B     TXmode(a2),d3      add Tx h/w handshake mode
                MOVE.B   d3,MPSMode(a3)     set no. of stop bits/Tx control
                MOVE.B   d0,Parity(a2)      save current mode
                TST.B    RTSstate(a2)       need to assert RTS ?
                BEQ.S    BitPar20           ..no; bra on
                BSR      EnabRTS            go assert RTS line manually
      BitPar20  MOVE.W   (sp)+,sr           restore irq masks
                MOVEA.L  (sp)+,a0           restore a0
                rts                         return (carry clear)

      TabPar
020e 10         dc.b     $10                no parity
020f 04         dc.b     $04                odd parity
0210 ff         dc.b     $ff                illegal value
0211 00         dc.b     $00                even parity

      TabBC
 0212 03        dc.b     $03                8 bits per char
0213 02         dc.b     $02                7 bits per char
0214 01         dc.b     $01                6 bits per char
0215 00         dc.b     $00                5 bits per char

      TabSB
 0216 07        dc.b     $07                1 stop bit
0217 07         dc.b     $07                1.5 stop bits (for 5 bit data)
0218 0f         dc.b     $0F                2 stop bits
0219 ff         dc.b     $ff                illegal value
```

29.6 Read Routine

In this driver, the read routine does not actually touch the physical device. It is isolated from the device by the driver's interrupt routine. The interrupt routine places input characters on a queue. The read routine takes characters off the queue as required.

If the read routine were only responsible for reading, the code would be less than half its present size. It would follow this outline:

```
repeat
    mask interrupts
```

```
        if the queue is empty
            unmask interrupts
            sleep
            continue
    until the queue is not empty
    take a character off the queue
    unmask interrupts
    return the character
```

Flow control, XOn/XOff or hardware, is partly the responsiblility of the read routine. When the interrupt service routine notices that the queue is mostly full, it halts input by sending an XOff or dropping RTS and turning off input interrupts from the device. The interrupt service routine will set the InHalt flag to indicate that input is halted. When the queue is mostly empty and the driver is in InHalt state, the read routine sends an XOn, re-enable input interrupts, and turns off the InHalt flag.

When the read routine writes an XOn it does not go through the usual procedure. It checks the state of its output queue (that is, the output queue for the output part of the device). If the output queue is full, the read routine sets a flag that tells the output code to send an XOn. If the output queue is not full, the read routine places an XOn on the output queue.[8]

The set-signal mechanism could put a driver in a position where it should give a character of input to two separate processes. It protects itself from this predicament with a policy. If there is a signal pending, the read routine declares the device "not ready" to any other readers. So, if any process tries to read from a *device* (not a path) with a set-signal pending, the driver returns an error to the reader.

The critical section right after Read_a spans the branch to Read00. If the queue is empty, the routine registers itself as an interested party before it unmasks interrupts. Then it sleeps until some input arives.

If there is data in the queue the critical section was unneccessary. The routine re-enables interrupts and proceeds to take a character off the queue and adjust the counter and pointer. Although the dequeue involves several variables, the code that implements it is not a critical section. The variables it uses are either used only by this one section of code, or they are manipulated with one-instruction operations (the `sub.w` that is used to decrement InCount).

```
********************
* Read: Return one byte of input from the Mpsc
*
* Passed: (a1) = Path Descriptor
```

[8]There may be some possibility for trouble in the read routines technique of placing an XOn directly on its output queue. What if the output for this device doesn't control its input?

```
*       (a2) = Static Storage address
*       (a4) = current process descriptor
*       (a6) = system global ptr
*
* Returns: (d0.b) = input char
*
* Error Return: (cc) = carry set
*       d1.w = error code
*
* Destroys: a0
*
        Read00  MOVE.W V_BUSY(a2),V_WAKE(a2) arrange wake up signal
                MOVE.W (sp)+,sr              restore IRQs
                bsr     MpscSlep
        Read    tst.b   InHalt(a2)           is input halted?
                ble.s   Read_a               branch if not
                cmpi.w  #MinBuff,InCount(a2) buffer mostly emptied?
                bhi.s   Read_a               ..no; continue
                move.b  V_XON(a2),d1         get XOn char
                movea.l V_PORT(a2),a3        get port address
                move.w  sr,–(sp)             save current IRQ status
                move.w  IRQMask(a2),sr       mask IRQs
                BTST.B  #TxE_Bit,MPSBdSt(a3) transmit buffer empty?
                BEQ.S   Read10               no, signal XON ready to send
                CLR.B   InHalt(a2)           clean up XOFF flag
                MOVE.B  d1,MPSData(a3)       transmit XON character
                BRA.S   Read20               continue

        Read10  ORI.B   #Sign,d1             set Sign bit
                MOVE.B  d1,InHalt(a2)        flag input resume
                MOVEA.L BaseAddr(a2),a0      get port base address
                MOVE.B  Otpt_On(a2),d3
                MOVE.W Globl(a2),d0          get offset to global
                OR.B    d3,(a6,d0.w)         enable IRQs
                MOVE.B  (a6,d0.w),MPSImr(a0) put into register
        Read20  MOVE.W  (sp)+,sr             unmask IRQs

        Read_a  tst.w   SigPrc(a2)           a process waiting for device?
                bne.s   ErrNtRdy             ..yes; return dormant terminal error
                move.w  sr,–(sp)             save current IRQ status
                move.w  IRQMask(a2),sr       mask IRQs
                TST.W   InCount(a2)          any data?
                BEQ.S   Read00               branch if not
                MOVE.W  (sp)+,sr             unmask IRQs
                movea.l InEmpty(a2),a0       point to next char
                move.b  (a0)+,d0             get character
                subq.w  #1,InCount(a2)       dec buffer size by one
                cmpa.l  InEnd(a2),a0         at end of buffer?
                blo.s   Read_b               branch if not
```

```
         lea.l   InpBuf(a2),a0          point to start of buffer
Read_b   move.l  a0,InEmpty(a2)         update buffer pointer
         move.b  V_ERR(a2),PD_ERR(a1) copy I/O status to PD
         beq.s   Read90                 return if no error
         clr.b   V_ERR(a2)
         move.w  #E$Read,d1             signal read error
         ori.b   #Carry,ccr             return Carry set
Read90   rts

ErrNtRdy move.w  #E$NotRdy,d1
         ori.b   #Carry,ccr             return Carry set
         rts
```

29.7 Sleep

Sleep is called by the read and write entries. The routine sleeps until it is sent a signal. When it receives a signal it classifies the signal. A wakeup signal means that input or output has arived and the sleep routine should return to whoever called it (their data is ready). The interrupt routine sent a wakeup signal (signal 1), but OS-9 does not treat the wakeup signal like other signals. It moves the process from the sleeping queue to the active queue without storing a value in the P$Signal field.

The sleep routine considers three cases:

1. It is a deadly signal (less than 32). In this case, the sleep routine pops its return address off the stack and returns to its caller's caller with an error. This would, for instance, skip it around the read routine and directly back to the file manager with a keyboard interrupt.
2. The process sleeping in the driver died. In this case, it doesn't matter what the signal number is; the sleep routine returns as it does for a deadly signal.
3. It's not a deadly signal and the process has not expired. The sleep routine returns to its caller.

```
********************
* MpscSlep: Sleep until interrupt occurs
*
* Passed: (a2) = driver global storage
*     (a4) = current process descriptor ptr
*     (a6) = system global data ptr
*
* Returns: nothing
*
* Error Return: (cc) = carry set
*       d1.w = error code (signal)
*
* Destroys: possibly PC
*
        MpscSlep
                move.l  d0,-(sp)             save reg
                moveq.l #0,d0                sleep indefinitely
                os9     F$Sleep              wait for interrupt
                move.w  P$Signal(a4),d1      signal present?
                beq.s   ACSL90               ..no; return
                cmpi.w  #S$Deadly,d1         deadly signal?
                blo.s   ACSLER               ..yes; return error
        ACSL90  btst.b  #Condemn,P$State(a4) has process died?
                bne.s   ACSLER               ..yes; return error
                move.l  (sp)+,d0             restore register, clear carry
                rts

        ACSLER  addq.l  #8,sp                exit to caller's caller
                ori.b   #Carry,ccr           return Carry set
                rts
```

29.8 Write Routine

Like the read entry, the write entry relies on the interrupt service routine to do the low-level I/O. This write routine places data on the write queue that feeds the interrupt routine. The basic outline of the write routine is:

```
repeat
    mask interrupts
    if the queue is full
        unmask interrupts
        sleep
        continue
until the queue is not full
Put the output character on the queue
if the device isn't active for output
    activate it
unmask interrupts
return
```

The full outline isn't much more complicated.

```
repeat
    mask interrupts
```

```
        if the queue is full
            unmask interrupts
            sleep
            continue
    until the queue is not full
    put the output character on the queue
    clear the output buffer empty flag.
    if the queue was empty and the device was not XOff'ed
        activate the device for output
    unmask interrupts
    return
```

Most of the write code is one big critical section. It doesn't strictly have to be all one critical section; for instance, the queue update could be separated from the interrupt enable code. In this case the cost of enabling interrupts and then disabling them is not justified for the six instructions that enable output interrupts from the device.

The IMR device register may be shared with the clock and the instance of the driver handling the other side of the chip, so it is shadowed in OEM static memory and the shadow must be updated.

```
********************
* Write
* Output one character to Mpsc
*
* Passed: (a1) = Path Descriptor
*       (a2) = Static Storage address
*       (a4) = current process descriptor ptr
*       (a6) = system global data ptr
*       d0.b = char to write
*
* Returns: nothing
*
* Error Return: (cc) = carry set
*       d1.w = error code
*
       Write00  move.w V_BUSY(a2),V_WAKE(a2) arrange wake up signal
                move.w (sp)+,sr             restore IRQs
                bsr.s  MpscSlep             sleep a bit
       Write    move.w sr,-(sp)             save current IRQ status
                move.w IRQMask(a2),sr       mask IRQs
                move.w OutCount(a2),d2      get output buffer data count
                cmpi.w #OutSiz,d2           room for more data?
                bhs.s  Write00              ..no; wait for room
                addq.w #1,OutCount(a2)      increment byte count
                movea.l OutFill(a2),a0      point to next char location
                move.b d0,(a0)+             store char and inc pointer
```

```
         CMPA.L   OutEnd(a2),a0       end of buffer?
         BLO.S    Write10             branch if not
         LEA.L    OutBuf(a2),a0       point to start of buffer
Write10  MOVE.L   a0,OutFill(a2)      update buffer pointer
         BCLR.B   #H_Empty,OutHalt(a2) clear output buffer empty flag
         BEQ.S    Write80 ..if data was in buffer, no need to re-enable irqs
         BTST.B   #H_XOFF,OutHalt(a2) output currently halted ?
         BNE.S    Write80             ..yes; don't enable irqs
         MOVEA.L  BaseAddr(a2),a0     get device address
         MOVE.W   Globl(a2),d0        get offset to global
         MOVE.B   Otpt_On(a2),d3      get enable flag
         OR.B     d3,(a6,d0.w)        put into global register
         MOVE.B   (a6,d0.w),MPSImr(a0) put into register
Write80  MOVE.W   (sp)+,sr            unmask IRQs
         moveq.l  #0,d1               clear carry
         rts
```

29.9 GetStat Routine

In this driver, the getstat code is straightforward. It bounces along matching the option code against the option for blocks of code until it finds a match and exectutes a block, or gets to the end of the getstat code and returns an unknown SVC error code.

The most interesting entry in this device driver's getstat code is the getoptions block. Most of the work for getopts is done at a higher level—probably IOMan—but the driver is still called in this case. The driver synchronizes the path descriptor's option area with the device static storage. In particular, it updates the parity and format codes in the path descriptor.

None of the getstat code is in a critical section. The only multi-instruction update is in getstat options. Critical sections are only needed when a block of code must not be disturbed by an interrupt handler, and the interrupt handler for this driver never updates the baud rate or port protocol values.

```
********************
* GetStat: get device status
*
* Passed: (a1) = Path Descriptor
*       (a2) = Static Storage address
*       (a4) = process descriptor
*       (a5) = caller's register stack ptr
*       (a6) = system global data ptr
*       d0.w = status call function code
*
* Returns: varies with function code
*
```

```
* Error Return: (cc) = carry set
*      d1.w = error code
*
       GetStat
* return data available count
*
                   cmpi.w  #SS_Ready,d0        ready status?
                   bne.s   GetSta10            ..no
                   clr.w   R$d1(a5)            sweep high word of register
                   move.w  InCount(a2),R$d1+2(a5) return input char count
                   beq     ErrNtRdy            ..no data; return not ready error
                   rts                         (carry clear)

* return eof status
*
       GetSta10    cmpi.w  #SS_EOF,d0          end of file?
                   beq.s   GetSta99            ..yes; return (Carry clear)

* check for "get options"
*
                   cmpi.w  #SS_Opt,d0          get options call ?
                   bne.s   Unknown             ..no; return error for unknown request

* update path descriptor for currently active baud, parity
*
                   move.b  BaudRate(a2),PD_BAU(a1) set currently active baud rate
                   move.b  Parity(a2),PD_PAR(a1) set currently active comms mode
                   rts                         (carry clear)

* return error for unknown service requests
*
       Unknown     move.w  #E$UnkSvc,d1        unknown service code
                   ori.b   #Carry,ccr          return Carry set
       GetSta99    rts
```

29.10 PutStat Routine

The driver includes most of the standard putstats arranged in the following order:

SS_SSig
SS_Relea
SS_EnRTS
SS_DsRTS
SS_Opt
SS_Open
SS_Break

The order is important because the selection mechanism makes the earlier putstats slightly faster than those late in the list.

The device driver does not get called for every setstat code, but it may be called for things that don't interest it. For instance, an SCF device driver probably has no interest in path closings but it is called for each one. Many setstats are passed to the device driver as a hedge against unexpected developments in drivers. The appropriate response to an uninteresting setstat code is "unknown SVC."

```
********************
* PutStat: set device status
*
* Passed: (a1) = Path Descriptor
*       (a2) = Static Storage address
*       (a4) = process descriptor
*       (a5) = caller's register stack ptr
*       (a6) = system global data ptr
*       d0.w = status call function code
*
* Returns: varies with function code
*
* Error Return: (cc) = carry set
*       d1.w = error code
*
```

The `SS_SSig` setstat code ensures that no path is already waiting for the device (see the read routine for another related test). If no other path has tied up the input for this device, the code checks for input waiting. If there is input waiting, the setstat sends a signal immediately.

The rest of this function enables input interrupts[9] and saves data that will be used by the interrupt handler when the time comes to actually *send* the signal.

For this function, one critical section covers three activities. The actions are:

- Send a signal and return if there is data ready.
- Save the process ID, signal code, and path number for the interrupt routine.
- Enable output interrupts (and reflect the device register in the shadow register).

To see the need for the part of the critical section that spans the check for input and the storage of data, consider the results of queuing some input between those points:

The input queue is empty.
A program requests a signal when data is ready.

[9]Input and output interrupts are *both* enabled by storing Otpt_On into MPSImr.

The call gets to the device driver which checks the input queue.
Since the input queue is empty, the driver proceeds to register the signal.
BUT, a character arrives before the driver gets to the movem.w instruction.
The hardware interrupt from the 68681 is dispatched to the device driver's
        interrupt routine.
The interrupt routine checks for a pending signal and finds none.
It just queues the input.
The putstat code resumes execution and completes.

The driver is left with input in the queue and a signal that should be sent as soon as data appears in the input queue. If the program was waiting for that one character, it could now wait forever.

```
    PutStat
* signal process on data available
*
             cmpi.w  #SS_SSig,d0         signal process when ready?
             bne.s   PutSta_A            ..no
             tst.w   SigPrc(a2)          somebody already waiting?
             bne     ErrNtRdy            ..yes; error
             move.w  PD_CPR(a1),d0       get caller's process ID
             move.w  R$d2+2(a5),d1       get signal code
             move.w  sr,–(sp)            save IRQ status
             move.w  IRQMask(a2),sr      disable IRQs
             TST.W   InCount(a2)         any Data available?
             BNE.S   PutSta10            yes, signal Data ready
             MOVE.W PD_PD(a1),d2         get associated path #
             MOVEM.W d0–d2,SigPrc(a2)    save process id, signal, path #
             MOVEA.L BaseAddr(a2),a0     point to base address
             MOVE.W  Globl(a2),d0        get offset to global
             MOVE.B  Otpt_On(a2),d3      get enable flag
             OR.B    d3,(a6,d0.w)        or into global register
             MOVE.B  (a6,d0.w),MPSImr(a0) put into register
             MOVE.W  (sp)+,sr            unmask IRQs
             moveq.l #0,d1               clear carry
             rts

    PutSta10 MOVE.W  (sp)+,sr            restore IRQ status
             bra     SendSig             send the signal
```

The release device function is a slightly tricky piece of coding. What it *does* is:

- If signal-on-data-ready is set for this path and this process, clear it by setting the process ID for the signal to zero.

- If there is a signal-on-DCD-loss set for this path and this process, clear it by setting the process ID for the signal to zero.

The program saves a half dozen statements by calling the check and clear code as a subroutine. It saves an extra bsr.s and a rts by dropping through the subroutine instead of calling it a second time.

```
* release all signal conditions
*
        PutSta_A  cmpi.w  #SS_Relea,d0     release Device?
                  bne.s   PutSta_B         bra if not
                  move.w  PD_CPR(a1),d0    get process id
                  move.w  PD_PD(a1),d2     get associated path #
                  lea.l   SigPrc(a2),a3    check SigPrc
                  bsr.s   ClearSig
                  lea.l   DCDPrc(a2),a3    now check DCDPrc

        ClearSig  cmp.w   (a3),d0          is signal for this process ?
                  bne.s   ClearSig20       ..no; exit
                  cmp.w   4(a3),d2         does it concern this path ?
                  bne.s   ClearSig20       ..no; exit
                  clr.w   (a3)             clear down signal condition
        ClearSig20 moveq.l #0,d1           flag no error
                  rts                      return
```

The 68681 can perform hardware flow control with its RTS line. A program can also manipulate the line with the following setstats. They involve straightforward manipulation of the hardware. A custom device driver often includes many setstats of this general type.[10]

```
* RTS control
*
        PutSta_D  cmpi.w  #SS_EnRTS,d0     enable RTS
                  bne.s   PutSta_E         branch if not.
        EnabRTS   move.w  #MPSOPSet,d2     get SET register offset
                  st.b    RTSstate(a2)     flag RTS asserted
        EnabRTS10 move.bChanelNo(a2),d1    get channel number
                  moveq.l #0,d0            sweep d0
                  bset.l  d1,d0            select channel RTS o/p line
                  movea.l BaseAddr(a2),a0  get device base address
                  move.b  d0,(a0,d2.w)     condition appropriate state on channel
                  rts                      return (carry clear)
```

[10] Setstat and getstat routines are the official place to put strange, device-dependent code. If a chip offers a special service, this is the place to put support for that function. If, on the other hand, the chip requires special support, that should be hidden in the init routine and elsewhere. A device should never require the use of a non-standard set/getstat.

```
PutSta_E  cmpi.w  #SS_DsRTS,d0       disable RTS
          bne.s   PutSta_F           branch if not
DisablRTS move.w  #MPSOPClr,d2       get CLEAR register offset
          sf.b    RTSstate(a2)       flag RTS negated
          bra.s   EnabRTS10          go negate the line
```

SS_Opt is new to device drivers. It has been handled by IOMan, which simply copied the path options from the supplied buffer into the path descriptor.

After IOMan copies the options and SCF does anything it likes, the setstat is passed to the device driver. The driver checks for changes to the hardware configuration values in the path options and makes any changes neccessary to bring the device into correspondence with the descriptor.

The function compares the baud rate and communication mode in the path descriptor with the values in device static storage. If neither has changed, the function returns without modifying the hardware setup. If either has changed, the function calls the same routines the Init entry used to set the device configuration.

This function has no critical section itself, but it calls InitSP, BaudCalc, and BitPar; all of which include critical sections when they write to the chip and update shadow registers.

```
* change path options
*
PutSta_F  cmpi.w  #SS_Opt,d0         set options call ?
          bne.s   PutSta_G           branch if not

* here to check whether baud/parity have changed

CheckMode move.b PD_BAU(a1),d0       get baud rate current
          cmp.b   BaudRate(a2),d0    has it changed ?
          bne.s   ChngMode           ..yes; attempt to re-configure
          move.b  PD_PAR(a1),d1      get port configuration
          cmp.b   Parity(a2),d1      has communication mode changed ?
          beq.s   PutSta90           ..no; exit (nothing to do)
ChngMode movea.l V_PORT(a2),a3       get device port address
          bsr     InitSP             disable rx/tx
          bsr     BaudCalc           attempt new baud rate
          bcs.s   ChngExit           ..exit if error
          move.b  PD_PAR(a1),d0      get parity, etc
          bsr     BitPar             attempt to change com. mode
ChngExit  move.w  sr,-(sp)           save ccr status
          move.b  #RxEnabl!TxEnabl,MPSCntl(a3) re-enable rx/tx
          rtr                        restore ccr and return
```

When a new path is opened, the driver checks the path options against options in device static storage. Without this function and the previous function, the hardware options are only changed when the init entry is called (when the device is attached).

```
* new path open
*
       PutSta_G  cmpi.w   #SS_Open,d0          new path opened ?
                 beq.s    CheckMode            ..yes; check for configuration changes
```

Serial chips usually have a command that sends the break value, but the command is not sufficient to send an actual break. A break signal has both a value and a duration (which should be longer than the time it takes to send a character). You can't just write a break (though a $00 at a low baud rate will usually do the trick). To make a break, the driver has to set the chip to send the break value and wait a while, then tell the chip to stop sending a break.

This driver supports a break in two ways. If timed sleeps are supported (i.e., there is a working system clock), the setstat starts sending a break, sleeps for a specified interval; then stops sending the break value. If timed sleeps are not supported, the setstat delays by busy waiting instead of sleeping.

```
 * send BREAK out port
*
       PutSta_H  cmpi.w   #SS_Break,d0         send break ?
                 bne      Unknown              ..no; return error
                 movea.l  V_PORT(a2),a3        get device port address
                 move.b   #StartBrk,MPSCntl(a3) start the break
                 move.l   #BrkTime,d0          get "break time"
       Brk_Timedos9       F$Sleep              delay while break being sent
                 bcs.s    Brk_manual           do manual timing if no clock
                 tst.l    d0                   sleep the full time ?
                 beq.s    Brk_End              ..yes; go stop the break
                 bra.s    Brk_Timed            ..else, wait for break-time to expire

       Brk_manual move.w#5,d0                  outer counter
                 moveq.l  #−1,d1               iniz inner counter
       Brk_a     dbra     d1,Brk_a
                 dbra     d0,Brk_a
       Brk_End   move.b   #StopBrk,MPSCntl(a3) stop the break
                 rts                           (carry clear)

       PutSta90  moveq.l  #0,d1                clear Carry
                 rts
```

29.11 Terminate Routine

When a device is detached, IOMan calls its terminate routine. This code is responsible for shutting the device down in good order. The procedure includes these steps:

1. Wait for the output queue to empty.
2. If the driver/device supports hardware flow control, turn off RTS.
3. Shut down the device. In particular, disable its interrupts.
4. Take the driver out of the polling table.

It's important to take the steps in that order. If, for instance, the terminate routine disabled interrupts before the output queue was empty, output would halt and the queue would never empty. Any data left in the output buffer would be lost.

```
********************
* Term: Terminate Mpsc processing
*
* Passed: (a1) = device descriptor pointer
*       (a2) = static storage
*       (a4) = current process descriptor ptr
*       (a6) = system global data ptr
*
* Returns: none
*
* Error Return: (cc) = carry set
*       d1.w = error code
*
    TRMN00  MOVE.W V_BUSY(a2),V_WAKE(a2) arrange wake up signal
            MOVE.W (sp)+,sr            restore IRQs
            pea.l  Term(pc)            return to entry point if signals
            bsr    MpscSlep            wait for interrupt
            addq.l #4,sp               toss return address if no signals
    Term    move.w P$ID(a4),d0
            move.w d0,V_BUSY(a2)
            move.w d0,V_LPRC(a2)
            move.w sr,–(sp)            save current IRQ status
            move.w IRQMask(a2),sr      mask IRQs
            TST.W  OutCount(a2)        any data?
            BNE.S  TRMN00              sleep if there is
            TST.B  RTSstate(a2)        RTS asserted ?
            BEQ.S  Term20              ..no; no need to negate
            BSR    DisablRTS           go negate RTS line
    Term20  MOVEA.L BaseAddr(a2),a0    get port base address

            MOVE.B Otpt_On(a2),d1      get enable bits
```

```
        NOT.B   d1                  complement it
        MOVE.W  Globl(a2),d0        get offset to global
        BEQ.S   Term40              ..if zero; never got iniz'd
        AND.B   d1,(a6,d0.w)        disable interrupts
        MOVE.B  (a6,d0.w),MPSImr(a0) move to register
Term40  MOVE.W  (sp)+,sr            restore IRQ masks
        move.b  M$Vector(a1),d0 get vector #
        suba.l  a0,a0
        os9     F$IRQ               remove acia from polling tbl
        rts
```

29.12 Interrupt Handler

The interrupt handler has two primary tasks. It must determine whether an interrupt could have come from its device, and move data between the input/output queues and the device when the device originates an interrupt.

If several devices share an interrupt vector, the kernel calls each driver's interrupt handler until a driver finds that his device has asserted an interrupt. When a driver accepts the interrupt, the kernel assumes that the driver will deal with the interrupt.

The interrupt handler is entered with its interrupt masked. This means that the entire interrupt handler is one big critical section. The driver should keep its interrupt handler code as fast as possible to prevent lost interrupts. If the interrupt handler must be long, consider ending the critical section early by enabling the device's interrupt.

First the interrupt handler classifies the interrupt. Is it from "my" device? Is it input or output for channel A or B?

```
********************
* MPSCIRQ: Process interrupt (input or output) from Mpsc
*
* Passed: (a2) = Static Storage addr
*       (a3) = port address ptr
*       (a6) = system global data ptr
*
* Returns: (cc) = carry set if false interrupt, else clear
*
* Destroys: May only destroy D0, D1, A0, A2, A3, and A6. Any
*       other registers used MUST be preserved.
*


* Exit here if no interrupts

MPSIRQEx ori.b  #Carry,ccr          return with carry set
        rts
```

```
MPSCIRQmovea.l BaseAddr(a2),a0      point to base of port
       move.b  MPSImr(a0),d1        get IRQ status register
       move.w  Globl(a2),d0         get offset to global
       and.b   (a6,d0.w),d1         mask out disabled interrupts
       move.l  a3,d0                get port address
       btst.l  #ABbit,d0            is this channel B?
       beq.s   MIRQ.a               if channel A, branch

* Note! Check for receive interrupt first.
*
       andi.b  #IRQP_BitB,d1        mask off all except B interrupts
       beq.s   MPSIRQEx             if no interrupts, branch
       btst.l  #IRQ_RecB,d1         is this a rec interrupt?
       beq.s   OutIRQ               if not, branch
       bra.s   MPSIRQ.c             branch if rec irq

MIRQ.a andi.b  #IRQP_BitA,d1        mask off all except A interrupts
       beq.s   MPSIRQEx             if no interrupts, branch.
       btst.l  #IRQ_RecA,d1         is this a recv interrutpt?
       beq.s   OutIRQ               if not, branch
```

For both input and output interrupts, the interrupt handler attempts to send XOn or XOff values that are pending. These values are saved as pending output if the output buffer is full. The objective is to write them as soon as possible, so the interrupt handler looks for an opportunity to write the pending character. It doesn't write the character by enqueing it; this routine writes the control character directly into the output register.

```
MPSIRQ.c move.b InHalt(a2),d1       XOn or XOff waiting to be sent?
       bpl     InIRQ                handle input IRQ if not
       btst.b  #TxE_Bit,MPSBdSt(a3) transmit buffer empty?
       beq     InIRQ                handle input IRQ if not
       bclr.l  #Signbit,d1          clear Sign bit
       move.b  d1,MPSData(a3)       send character
       move.b  V_XON(a2),d0         get XOn value
       eor.b   d0,d1                get Zero if XOn
       move.b  d1,InHalt(a2)        mark it sent
       bra     InIRQ                handle input IRQ
```

InHalt can be in one of three states:

- If the sign bit (high-order bit) is set, the remainder of the byte holds an XOn or XOff. This character is pending.
- If the sign bit is off but the byte is not zero, input has been halted by an XOff.

- If the byte is zero, the device is not halted and there is no XOff pending.

The following code is entered if the entry code of the interrupt handler determines that this is an output interrupt. First the routine handles any pending XOn/XOff characters. Since the driver knows that it just got an output interrupt, it does not need to check to know that the output buffer is empty. It simply writes the pending character and returns to the kernel just as if it had taken a character out of the output queue.

```
********************
* OutIRQ: Mpsc output interrupt service
*
* Passed: (a0) = device base address
*         (a2) = static storage address
*         (a3) = device port address
*         (a6) = system global data ptr
*         d1.b = device status register contents
*
        OutIRQ  move.b  InHalt(a2),d0       send XOn or XOff?
                bpl.s   OutI_a              branch if not
                bclr.l  #Signbit,d0         clear Sign bit
                move.b  d0,MPSData(a3)      send character
                move.b  V_XON(a2),d1        get XOn value
                eor.b   d1,d0               get Zero if XOn
                move.b  d0,InHalt(a2)       mark it sent
                tst.b   OutHalt(a2)         is output halted?
                bne.s   OutIRQ3             branch if so
                rts
```

The simplified overview of the output interrupt handler is:

- If there is any data in the output queue, the handler dequeues one byte and writes it to the output device.
- If there is no data in the output queue, the handler turns off output interrupts.

The code is only slightly more complicated than the simplified version. If output is suspended, it must have been suspended after the last character was written (at most one character can be written after output is suspended). The interrupt routine responds to the suspended output flag by disabling output interrupts, even if there is still data in the output queue.

When the output queue is almost full, the write routine will sleep when it attempts to enqueue more data. The interrupt handler must detect that a process is sleeping in write and signal him that there is now room to continue.

The writer could be wakened whenever the queue has any space at all, but the driver lets the queue empty substantially before releasing the writer. This prevents a busy writer from sleeping on every character written. Since a write that includes a sleep and a signal is slower than a write that simply enqueues a byte, the lag in the queue improves efficiency.

If there is no data in the queue awaiting output, the code shuts down output interrupts from the device and sets a flag that indicates that output is halted because of an empty buffer (the other reason for halted output is an XOff from the other end).

```
OutI_a   btst.b   #H_XOFF,OutHalt(a2) is output suspension requested ?
         bne.s    OutIRQ3             ..yes; go disable interrupts
         move.w   OutCount(a2),d1     any Data in buffer?
         beq.s    OutIRQ2             branch if not
         subq.w   #1,d1               taking one char
         move.l   a1,-(sp)            save a1
         movea.l  OutEmpty(a2),a1 get pointer to next char
         move.b   (a1)+,MPSData(a3) put Data in acia
         cmpa.l   OutEnd(a2),a1       end of buffer?
         blo.s    OutI_1              branch if not
         lea.l    OutBuf(a2),a1       point to start
OutI_1   move.l   a1,OutEmpty(a2) update pointer
         movea.l  (sp)+,a1
         move.w   d1,OutCount(a2)     update char count
         cmpi.w   #MinBuff,d1         ready for more data?
         bhi.s    Wake90              exit if not
         tst.w    d1                  output buffer empty?
         bne.s    WakeUp              just wake up if not
OutIRQ2  bset.b   #H_Empty,OutHalt(a2) flag halted; buffer empty

OutIRQ3  move.w   Globl(a2),d0        get offset to global
         move.b   Otpt_Off(a2),d1     get disable mask
         and.b    d1,(a6,d0.w)        disable interrupts in global register
         move.b   (a6,d0.w),MPSImr(a0) write to register

WakeUp   move.w   V_WAKE(a2),d0       owner waiting?
         beq.s    Wake90              ..no; return
         clr.w    V_WAKE(a2)
         moveq.l  #S$Wake,d1          wake up signal

SendSig  os9      F$Send              wake up process

Wake90   moveq.l  #0,d1               clear carry
         rts
```

The simplified action of the input interrupt handler is:

Fetch a byte from the 68681's input register.

```
    Enqueue the character in the input queue.
    If there is a process waiting for input, wake it.
```

Three features are added to this simplified outline. The input character is checked against a set of special characters: quit, pause, XOff, etc., a signal on data ready request is accommodated, and there is a special case to deal with a full input queue.

The input byte is checked against special values stored in the device static storage. These values are copies of codes from the path descriptor which the file manager copies into the static storage every time it calls the driver. This sounds inefficient, but the interrupt handler does not get access to a path descriptor (it would be difficult to determine which path descriptor to use for a given character of input). If it matches any of these characters, the handler branches off to special code for that control character.

The code for a null control character is $00. The input routine must pass null characters through without treating them as the first null control character. Several drivers have failed because they were careless about null values in input. Since terminals don't ordinarily send nulls, the drivers would cause mysterious problems when XModem or some other binary-transfer program was running.

If the input queue is almost full, the interrupt routine notices the condition and sets an XOff-pending in InHalt. If the queue is actually full, the routine declares an error. (See the second half of InIRQ1.)

```
********************
* InIRQ: Mpsc input interrupt service
*
* Passed: (a0) = device base address
*       (a2) = static storage address
*       (a3) = device port address
*       (a6) = system global data ptr
*

* Notice the Absence of Error Checking Here

    InIRQ    move.b  MPSBdSt(a3),d1     get error status
             andi.b  #InputErr,d1       any errors?
             beq.s   InIRQ.a            branch if not
             or.b    d1,V_ERR(a2)       update cumulative errors
             move.b  #ErrorRst,MPSCntl(a3) reset special error condition
    InIRQ.a  move.b  MPSData(a3),d0     read input char
             beq.s   InIRQ1             ..NULL, impossible ctl chr
             cmp.b   V_INTR(a2),d0      keyboard Interrupt?
             beq     InAbort            ..Yes
             cmp.b   V_QUIT(a2),d0      keyboard Quit?
             beq     InQuit             ..Yes
             cmp.b   V_PCHR(a2),d0      keyboard Pause?
```

```
         beq     InPause            ..Yes
         cmp.b   V_XON(a2),d0       XOn continue?
         beq     InXON              ..Yes
         cmp.b   V_XOFF(a2),d0      XOff Immediate Pause request?
         beq     InXOFF             ..Yes

InIRQ1   move.l  a1,–(sp)           save a1
         movea.l InFill(a2),a1      point to current char
         move.b  d0,(a1)+           put Data in buffer
         addq.w  #1,InCount(a2)     count character
         cmpi.w  #InpSiz,InCount(a2) buffer full?
         bls.s   InIRQ10            branch if not
         subq.w  #1,InCount(a2)     uncount character
         ori.b   #IPOverrun,V_ERR(a2) simulate ip over-run error
         move.l  (sp)+,a1           restore a1
         bra     WakeUp             exit
InIRQ10  cmp.l   InEnd(a2),a1       end of buffer?
         blo.s   InIRQ30            branch if not
         lea.l   InpBuf(a2),a1      point to start of buffer
InIRQ30  move.l  a1,InFill(a2)      update next in pointer
         move.l  (sp)+,a1           restore a1
```

If any process requested a signal on data ready, send that signal. This is done *before* the queue is checked for impending overflow. Since a send signal on data ready can only be set when the queue is empty and it is turned off after it is sent, the branch to send the signal (and not check for queue overflow) is only taken when there is exactly one character in the queue.

```
         move.w  SigPrc(a2),d0      any process to notify?
         beq.s   InIRQ4             ..no
         move.w  SigPrc+2(a2),d1    get signal code
         clr.w   SigPrc(a2)         disable signal sending
         bra     SendSig            signal waiting process & return
```

If the input queue is almost full, arrange to have an XOff sent—unless one has already been sent. The procedure is:

```
If the input queue is almost full
    Get the XOff character from static storage.
    If XOff has not been sent already
        Clear the sign bit in the static storage XOff value.
        Store XOff with the sign bit set in InHalt.
        Enable output interrupts (so the XOff can be written).
```

```
InIRQ4   move.b  V_XOFF(a2),d0      get XOff char
```

```
        beq.s   InIRQ9              branch if not enabled
        cmpi.w  #MaxBuff,InCount(a2) is buffer almost full?
        blo.s   InIRQ9              bra if not
        move.b  InHalt(a2),d1       have we sent XOFF?
        bne.s   InIRQ9              yes then don't send it again
        bclr.l  #Signbit,d0         insure Sign clear
        move.b  d0,V_XOFF(a2)
        ori.b   #Sign,d0            set Sign bit
        move.b  d0,InHalt(a2)       flag input halt
        move.w  Globl(a2),d0        get offset to global
        move.b  Otpt_On(a2),d1      get enable flag
        or.b    d1,(a6,d0.w)        write into global register
        move.b  (a6,d0.w),MPSImr(a0) write to device register
```

If more input is waiting in the 68681, handle it immediately. This is more efficient than returning to the kernel and getting another input interrupt.

```
InIRQ9  btst.b  #RxA_Bit,MPSBdSt(a3) any more input available?
        beq     WakeUp              exit if not
        bra     InIRQ               go get it if so
```

Each input control character branches into one of the blocks below. They take the appropriate action, then branch back into the main input handler where they are treated like any other input. XOn and XOff are an exception to this rule, *XOn and XOff are not queued as ordinary input.*

XOn and XOff are flow-control characters. They refer specifically to a single serial port. The pause character is an OS-9 protocol character. It refers to the associated output device. The output device may not be the output part of a serial connection. The V_DEV2 field in the static storage (and the corresponding field in the device descriptor) are used to indicate the output device that corresponds to an input device. This is usually output side of the same device, but not always.

```
********************
* Control character routines
*
* Passed: (a0) = device base address
*       (a2) = static storage ptr
*       (a3) = device port address
*       (a6) = system global data ptr
*       d0.b = received input character
*
InPause tst.l   V_DEV2(a2)          any echo device?
        beq     InIRQ1              buffer char and exit if not
        move.l  a1,-(sp)            save it
        movea.l V_DEV2(a2),a1       get echo device static ptr
```

```
         move.b  d0,V_PAUS(a1)       request pause
         move.l  (sp)+,a1            restore it
         bra     InIRQ1              buffer char and exit

InAbort  moveq.l #S$Intrpt,d1        keyboard INTERRUPT signal
         bra.s   InQuit10

InQuit   moveq.l #S$Abort,d1         abort signal

InQuit10 move.b  d0,–(sp)            save input char
         move.w  V_LPRC(a2),d0       last process ID
         beq.s   InQuit90            ..none; exit
         clr.w   V_WAKE(a2)
         os9     F$Send              send signal to last user
InQuit90 move.b  (sp)+,d0            restore input char
         bra     InIRQ1              buffer char, exit

InXON    bclr.b  #H_XOFF,OutHalt(a2) enable output
         tst.b   OutHalt(a2)         still halted (buffer empty)?
         bne.s   InXExit             exit if so
         move.w  Globl(a2),d0        get offset to global
         move.b  Otpt_On(a2),d1      get enable flag
         or.b    d1,(a6,d0.w)        write into global register
         move.b  (a6,d0.w),MPSImr(a0) write into register
         btst.b  #TxE_Bit,MPSBdSt(a3) output buffer empty?
         beq.s   InXExit             exit if not
         bra     OutIRQ              start output if so

InXOFF   bset.b  #H_XOFF,OutHalt(a2) flag output restricted
         movea.l BaseAddr(a2),a0
         move.w  Globl(a2),d0        get offset to global
         move.b  Otpt_Off(a2),d1     get transmit disable flag
         and.b   d1,(a6,d0.w)        write into global register
         move.b  (a6,d0.w),MPSImr(a0) write to device register
InXExit  moveq.l #0,d1               clear carry
         rts
         ends
```

This driver is a full-featured SCF driver. It is a typical driver for an ordinary serial port. A much simpler driver can be constructed by leaving out the interrupt handling and queuing capability and simply polling for input and output. This driver would waste system resources, but it is a fast way to get a device driver written. This is a good way to write an experimental driver, but it should not be used in a real driver unless the I/O device does not generate interrupts, or the device reponds to all requests in no more than about a tenth of a millisecond.

Much complexity might be added to a driver. First, the driver reflects the complexity of the underlying hardware. If the I/O device were more intelligent and the driver chose to take advantage of it, the driver would be likely to grow quite elaborate. The getstat and putstat routines are especially likely to grow. They are the areas where special tricks are normally inserted.

Sometimes device drivers include chunks of logic that would ordinarily go in a program. This is done when response time requirements don't permit control to travel out to a higher level in the system, then back. The driver in this chapter, and every other SCF driver, includes code for flow control on an associated device: a good example of code that has been placed in a driver for efficiency.

Chapter 30

An RBF Device Driver

This chapter presents a complete RBF device driver written almost entirely in C.

By far the most difficult part of writing the driver in this chapter was understanding the controller and disk drive well enough to write code to control them.

Although this driver is a good starting point for other drivers, it is not a generic driver. I chose simple hardware and made simplifying assumptions whenever they didn't hide important aspects of driver construction. Still, more than half of the driver is specific to the GMX Micro-20 SCSI board, the Western Digital WD33C93A SCSI controller chip, and the Quantum Prodrive 105S hard disk drive. This is an example, not a general-purpose SCSI driver.

I try to avoid explanations of my hardware, but a driver is so hardware-specific that some of the code looks magical or senseless without some understanding of the underlying hardware.

30.1 Hardware Overview

The GMX Micro-20 uses a MC68020 processor, but since the bulk of the driver is written in C, the driver is mostly independent of the processor. I know of one processor-dependency: the code that sets the disk's sector size uses an I/O buffer with odd alignment. This causes the code (in the Exec() function) that copies data between the SCSI board and memory to use the 68020's ability to handle unaligned data.

The GMX SCSI interface board is memory mapped to a block of 32 bytes (see table 30.1.)

The SCSI controller cannot DMA directly into the Micro-20's memory, but it has DMA access to 128 kilobytes of RAM on the SCSI board. The driver could use WD33C93A programmed I/O, but performance would suffer. The higher perfor-

Table 30.1: SCSI Board Memory Map

Offset	Mode	Size	Description
0	Read	byte	WD33C93A Auxiliary Status Register
0	Write	byte	WD33C93A Address Register
1	Read/Write	byte	WD33C93A Internal Registers
2	Read	byte	Board Status Register
2	Write	byte	Board Control Register
8	Read/Write	word/long	Data buffer
12	Write	word	Data buffer address
14	The remainder of the 32-byte block is reserved		

Two bits in the board control register are useful: the high-order bit enables interrupts from the SCSI board, and bit six asserts the SCSI bus reset line and resets the WD33C93A.
The high-order bit in the board status register is set if the WD33C93A interrupt output is asserted.

mance option is to use DMA between the WD33C93A and the SCSI board's memory and use the processor to copy data between main memory and the SCSI board.

Both DMA and access by the CPU depend on the address selected by the *Data buffer address*. This register in the SCSI board's memory map controls the starting address for DMA or CPU access. Reads or writes by the WD33C93A or by the driver will start at the address placed in the data buffer address register and hit successive addresses on subsequent accesses. For instance, setting the data buffer address to 20 and reading a word from the data buffer four times:

```
for(i=0;i<4;++i)
    *ptr++ = Board_Data_Buffer;
```

will get data from the board's memory in the address range from 20 to 27.

The WD33C93A's internal registers are described in figure 30.1. There are several classes of register:

- The first two registers don't have register numbers. They have private memory mapped addresses. All the other registers share a single memory mapped address. They are accessed by writing a register number into the register select register, then reading or writing the address allocated to the selectable registers.

  The selected register auto-increments. If a program writes three to the register select register, then reads a byte from the "Internal registers" address four times, the program will receive the values of registers three, four, five, and six.

- Registers three through fourteen are dual-use registers. When the WD33C93A is given a *translate address* command, the registers use their main descriptions. The alternate descriptions are used for *Select and transfer* commands.

- Select and transfer can also user Register 0, but it is only required for SCSI command blocks that are not known to the WD33C93A.

This driver uses *select and transfer* for all SCSI commands. This is a powerful simplifying rule. In particular, it avoids a problem with register selection: there is no way for the interrupt service routine to save and restore the number of the WD33C93A's selected register. If the interrupt service routine needs to use any WD33C93A register other than auxiliary status, it may disrupt the interrupted code. Even if the interrupt service routine only reads whatever register has been selected by the body of the driver, the auto-increment will change the selected register and the interrupted code's next access to a selectable register will get the register after the last register accessed by the interrupt service routine (due to auto-increment) unless the register select register is written before accessing another register.

The only general solutions to this problem are: don't write the register select register from the interrupt service routine, or mask interrupts to the level of the device over every interval from register select through the last access depending on that selection.

The simplest type of select and transfer runs with no intervention from the interrupt service routine; since this driver uses only simple select and transfer, the interrupt service routine's only access to the WD33C93A is a read of the auxiliary status register. This is safe.

30.1.1 The Quantum Disk Drive

The hardware details of the Quantum Prodrive 105S used to test this driver had little impact on the driver (which speaks well for the drive). The mode-sense/mode-select code that the driver uses to set the sector size threads its way through vendor-specific pages of information, but I think this driver's mode select and mode set code is fairly generic.

The driver contains at least one assumption that is true for most embedded-SCSI devices, but not a SCSI rule. The driver silently uses a constant zero as the logical unit number of the target device. To make this driver handle devices with a logical unit number other than zero, the pd_lun field from device options would have to be stored in the CDB for each SCSI command.

30.2 The Driver's Main Entries

Figure 30.1: WD33C93A Device Registers

Mode	Description	Other Description	Register Number
R	Auxiliary status		
W	Register select		
R/W	Own ID	CDB size	0
R/W	Control register		1
R/W	Timeout period		2
R/W	Total sectors	CDB 1st byte	3
R/W	Total heads	CDB 2nd byte	4
R/W	Total cylinders (msb)	CDB 3rd byte	5
R/W	Total cylinders (lsb)	CDB 4th byte	6
R/W	Logical address (msb)	CDB 5th byte	7
R/W	Logical address (byte 2)	CDB 6th byte	8
R/W	Logical address (byte 3)	CDB 7th byte	9
R/W	Logical address (lsb)	CDB 8th byte	10
R/W	Sector number	CDB 9th byte	11
R/W	Head number	CDB 10th byte	12
R/W	Cylinder number (msb)	CDB 11th byte	13
R/W	Cylinder number (lsb)	CDB 12th byte	14
R/W	Target LUN		15
R/W	Command phase		16
R/W	Synchronous transfer		17
R/W	Transfer count (msb)		18
R/W	Transfer count (byte 2)		19
R/W	Transfer count (lsb)		20
R/W	Destination ID		21
R/W	Source ID		22
R	SCSI Status		23
R/W	Command		24
R/W	Data register		25
R	Auxiliary status		31

30.2.1 Init

```
#include <rbf.h>
#include <errno.h>
#include "drvr.h"
#include "lowlevel.h"

void IRQRtn(void );          /*Assembly language routine */
void InitStatics(MyStatics);

int Init(mod_dev *dd, MyStatics DevStatics, void *SysGlobs)
{
    register struct rbf_opt *Options;
    Board port;
    int Error;



    InitStatics(DevStatics);                                            /* pg. 435 */
    Options = (struct rbf_opt *)&(dd->_mdtype);
    port = (Board)DevStatics->v_sysio.v_port;

    if((Error = SetIRQ(dd->_mvector, dd->_mpriority, IRQRtn, DevStatics,   /* pg. 475 */
            port)) != 0)
        return Error;
    if((DevStatics->EvID = MakeEvent((ulong)port, &Error)) == -1){     /* pg. 454 */
                DevStatics->EvID = 0;
            return Error;
    }
    ClaimController(DevStatics->EvID);                                  /* pg. 479 */

    if(QueryWDOwn(SysGlobs) == 0){       /*Has the chip been initialized ? *//* pg. 473 */
        Error = Init33C93A(port, (Options->pd_scsiopt & SCSI_PARITY) != 0);/* pg. 436 */
        SetWDOwn((port->BD_STATUS & 0x07) | WD_OWNID_EAF | WD_OWNID_FS2,
                SysGlobs);                                              /* pg. 473 */
    }
    ReleaseController(DevStatics->EvID);                                /* pg. 479 */
    return Error;

}


void InitStatics(MyStatics DevStatics)
{
    register int i;

    DevStatics->v_ndrv = RBF_MAXDRIVES;
    for(i = 0 ; i < RBF_MAXDRIVES; ++i){
        DevStatics→drv[i].v_0.dd_tot[0] = 0x0ff;
        DevStatics→drv[i].v_0.dd_tot[1] = 0x0ff;
        DevStatics→drv[i].v_0.dd_tot[2] = 0x0ff;
    }
}


int Init33C93A(Board port, boolean ParityP)
{
    u_char OwnVal;

    (void)GET_SCSI_STATUS(port);        /* Touch the SCSI status register */
    /*
        Store the right value in the 33C93A OwnID register This includes the
        SCSI ID for this board and a bit to tell the 33C93A to turn on its
        advanced features.
    */
    OwnVal =(port→BD_STATUS & 0x07) | WD_OWNID_EAF | WD_OWNID_FS2;
    SET_OWNID(port, OwnVal);
    /*
        Now reset the chip.
    */
    if(Do_WD_Reset(port) != 1)                                  /* pg. 459 */
        return E_NOTRDY;        /* Couldn't reset */
    SET_SYNCTRANS(port, WD_STR_INIT_VALUE);
    Set_Control(port, (uchar)(ParityP ? (WD_CTL_DMWD | WD_CTL_EDI | WD_CTL_HSP) :
            (WD_CTL_DMWD | WD_CTL_EDI)));                       /* pg. 459 */
    return 0;
}
```

30.2.2 Term

```
#include <module.h>
#include <rbf.h>
#include "drvr.h"

int Term(mod_dev *dd, MyStatics DevStatics)
{
    register Rbfdrive DTableE;
    register int i;
    /*Take this controller out of the IRQ list */
    if(DevStatics→EvID != 0)
        ClaimController(DevStatics→EvID);                                   /* pg. 479 */
    SetIRQ(dd→_mvector, 0,(void *)0, DevStatics, (Board)0);                 /* pg. 475 */

    /*Free any memory attached to pointers in static storage */
    for(i=0; i < RBF_MAXDRIVES; ++i){
        DTableE= &(DevStatics→drv[i]);
        if(DTableE→v_sczero != (Sector0)0)       /*Free sector 0 buffer */
            DoSRtMem(DTableE→v_sczero, DTableE→v_dtext);                    /* pg. 472 */
    }
    if(DevStatics→EvID != 0){
        ReleaseController(DevStatics→EvID);                                 /* pg. 479 */
        /*Delete the event */
        DeleteEvent((ulong)DevStatics→v_sysio.v_port, DevStatics→EvID);     /* pg. 455 */
    }
    return 0;
}
```

30.2.3 Read

```
#include <errno.h>
#include "drvr.h"

int ReadDisk(int ct, u_int32 lsn, Pathdesc pathd,
MyStatics DevStatics, void *SysGlobs)
{
    register uchar *Buffer;
    register struct rbf_opt *Options;
    register Rbfdrive DTableE;
    register ulong StartAddr = lsn;
    int Error, retries;

    if(ct == 0)         /*If read is for no sectors, do no work */
        return 0;

    /*Make some useful pointers */
    Buffer = pathd→path.pd_buf;
    Options = (struct rbf_opt *)&(pathd→path.fm_opt);
    DTableE = pathd→path.fm_pvt.rbf.pd_dtb;

    if((Error = Cond_InitDrive(DevStatics, Options, DTableE, SysGlobs)) != 0)  /* pg. 447 */
        return Error;
```

```
/*Make a "real" lsn by adding lsnoffset and trackoffset */
StartAddr = addoffsets(lsn, Options→pd_lsnoffs,                    /* pg. 455 */
        (Options→pd_cntl & CNTL_AUTOSIZE) != 0,
        Options→pd_toffs, Options→pd_t0s,
        Options→pd_sct, Options→pd_sid);

/*
    If the caller thought he was asking for sector 0, do special sector 0 things.
*/

if(lsn == 0)
    if((Error = ReadSector0(StartAddr, DevStatics,                 /* pg. 446 */
            Buffer, DTableE, Options)) == 0){
        ++StartAddr;
        ++lsn;
        ct−−;
        Buffer += Options→pd_ssize;
    }else
        return Error;

if(ct == 0)          /*Nothing left to read */
    return 0;

if((Error = BoundsCheck(lsn, ct, DTableE→v_0.dd_tot[2] +           /* pg. 456 */
        256 * (DTableE→v_0.dd_tot[1] +
        256 * DTableE→v_0.dd_tot[0]),
        DevStatics→v_Bytes > Options→pd_maxcnt)) != 0)
    return Error;
for(retries = RETRY_MAX; retries >0; −−retries){
    Error = BaseRead(ct, StartAddr, Buffer, Options,               /* pg. 439 */
            DevStatics);
    switch(Error){
        case E_DIDC:
            /*disk ID change (perhaps reset) */
            /*Re-init drive and try again.  */
            (void)InitDrive(                                       /* pg. 448 */
                    (Board)DevStatics→v_sysio.v_port,
                    (Options→pd_cntl & CNTL_NOFMT) != 0,
                    (Options→pd_scsiopt & SCSI_PARITY) != 0,
                    &(Options→pd_ssize),
                    Options→pd_ctrlrid,
                    DevStatics,
                    (void **)&(DTableE→v_sczero),
                    &(DTableE→v_init),
                    &(DTableE→v_dtext),
                    SysGlobs);
                break;
            case E_HARDWARE:
                ClaimController(DevStatics→EvID);                       /* pg. 479 */
                Error = Init33C93A((Board)DevStatics→v_sysio.v_port,    /* pg. 436 */
                        (Options→pd_scsiopt & SCSI_PARITY) != 0);
                ReleaseController(DevStatics→EvID);                     /* pg. 479 */
                if(Error == 0)
                    break;
                else
                    return Error;
            default:
                return Error;
        }
    }
    return Error;
}

int BaseRead(int ct, u_int32 StartAddr, u_char *Buffer,
        struct rbf_opt *Options, MyStatics DevStatics)
{
    int Error;

    DevStatics→v_Sectors = ct;
    DevStatics→v_Bytes = ct * Options→pd_ssize;

    SETUP_CMD(DevStatics→V_CDB, SCSI_READOP, StartAddr, ct);
    ClaimController(DevStatics→EvID);                                   /* pg. 479 */

    Error = Exec(READ_CMD_LEN, WD_DPD_In,                               /* pg. 456 */
            (u_int32 *)Buffer, Options→pd_ctrlrid,
            DevStatics);
    ReleaseController(DevStatics→EvID);                                 /* pg. 479 */
    return Error;
}
```

30.2.4 Write

```
#include <errno.h>
#include "drvr.h"

int WritDisk(int ct, u_int32 lsn, Pathdesc pathd,
        MyStatics DevStatics, void *SysGlobs)
{
```

```
register uchar *Buffer;
register struct rbf_opt *Options;
register Rbfdrive DTableE;
register ulong StartAddr = lsn;
int Error, Retries;

if(ct == 0)        /*If write is for no sectors, do no work */
    return 0;

/*Make some useful pointers */
Buffer = pathd→path.pd_buf;
Options = (struct rbf_opt *)&(pathd→path.fm_opt);
DTableE = pathd→path.fm_pvt.rbf.pd_dtb;

if((Error = Cond_InitDrive(DevStatics, Options, DTableE, SysGlobs)) != 0)  /* pg. 447 */
    return Error;

if(lsn == 0)
    if((Options→pd_cntl & CNTL_NOFMT) != 0)
        /*Can't write sector zero if format is inhibited */
        return E_FORMAT;
    else
        DTableE→v_zerord = FALSE;

    /*Make a "real" lsn by adding lsnoffset and trackoffset */
    StartAddr = addoffsets(lsn, Options→pd_lsnoffs,                  /* pg. 455 */
            (Options→pd_cntl & CNTL_AUTOSIZE) != 0,
            Options→pd_toffs, Options→pd_t0s,
            Options→pd_sct, Options→pd_sid);
    if((Error = BoundsCheck(lsn, ct, DTableE→v_0.dd_tot[2] +         /* pg. 456 */
            256 * (DTableE→v_0.dd_tot[1] +
            256 * DTableE→v_0.dd_tot[0]),
            DevStatics→v_Bytes > Options→pd_maxcnt)) != 0)
        return Error;

    for(Retries = RETRY_MAX; Retries >0; −−Retries){
        Error = BasicWrite(ct, StartAddr, Buffer, Options,              /* pg. 441 */
            DevStatics);
        switch(Error){
            case E_DIDC:
                /*disk ID change (perhaps reset) */
                /*Re-init drive and try again. */
                (void)InitDrive(                                        /* pg. 448 */
                        (Board)DevStatics→v_sysio.v_port,
                        (Options→pd_cntl & CNTL_NOFMT) != 0,
                                         (Options→pd_scsiopt & SCSI_PARITY) != 0,
                                         &(Options→pd_ssize),
                                         Options→pd_ctrlrid,
                                         DevStatics,
                                         (void **)&(DTableE→v_sczero),
                                         &(DTableE→v_init),
                                         &(DTableE→v_dtext),
                                         SysGlobs);
                    break;
                case E_HARDWARE:
                    ClaimController(DevStatics→EvID);                   /* pg. 479 */
                    Error = Init33C93A((Board)DevStatics→v_sysio.v_port,        /* pg. 436 */
                    (Options→pd_scsiopt & SCSI_PARITY) != 0);
                    ReleaseController(DevStatics→EvID);                 /* pg. 479 */
                    if(Error == 0)
                        break;
                    else
                        return Error;
                default:
                    return Error;
            }
        }

        return Error;
    }

int BasicWrite(int ct, u_int32 StartAddr, u_char *Buffer,
        struct rbf_opt *Options, MyStatics DevStatics)
{
    int Error;

    DevStatics→v_Sectors = ct;
    DevStatics→v_Bytes = ct * Options→pd_ssize;

    SETUP_CMD(DevStatics→V_CDB, SCSI_WRITEOP, StartAddr, ct);

    ClaimController(DevStatics→EvID);                                   /* pg. 479 */

    if((Error = Exec(WRITE_CMD_LEN, WD_DPD_Out,                         /* pg. 456 */
            (u_int32 *)Buffer, Options→pd_ctrlrid,
            DevStatics)) == 0)
        if(Options→pd_vfy == 0){        /*verification requested */
            SETUP_CMD_10(DevStatics→V_CDB, SCSI_VERIFY, 0,
                    StartAddr, ct);
            DevStatics→v_Bytes = 0;
            Error = Exec(VERIFY_CMD_LEN, WD_DPD_In,
                    (u_int32 *)0, Options→pd_ctrlrid,
                    DevStatics);
        }
    ReleaseController(DevStatics→EvID);                     /* pg. 479 */
    return Error;
}
```

30.2.5 GetStat and PutStat

```
#include <errno.h>
#include <sg_codes.h>
#include "drvr.h"
/*
    Profiles
*/
int DSize(MyStatics, struct rbf_opt *, REGISTERS *);

int GetStat(int Code, Pathdesc pathd, MyStatics DevStatics,
procid *procd, REGISTERS *regs, void *SysGlobs)
{
    register struct rbf_opt *Options;
    register Rbfdrive DTableE;
    int Error;

    Options = (struct rbf_opt *)&(pathd→path.fm_opt);
    DTableE = pathd→path.fm_pvt.rbf.pd_dtb;
    switch(Code){
        case SS_DCmd:
            if((Error = Cond_InitDrive(DevStatics,              /* pg. 447 */
                    Options, DTableE, SysGlobs)) != 0)
                return Error;
            return direct_command(regs, procd, Options, DevStatics);   /* pg. 466 */
        case SS_DSize:
            if((Error = Cond_InitDrive(DevStatics,              /* pg. 447 */
                    Options, DTableE, SysGlobs)) != 0)
                return Error;
            return DSize(DevStatics, Options, regs);            /* pg. 444 */
        case SS_VarSect:
            return Cond_InitDrive(DevStatics, Options,          /* pg. 447 */
                    DTableE, SysGlobs);
        default:
            return E_UNKSVC;
    }
}
```

```
int PutStat(int Code, Pathdesc pathd, MyStatics DevStatics,
        procid *procd, REGISTERS *regs, void *SysGlobs)
{
    register struct rbf_opt *Options;
    register Rbfdrive DTableE;
    int Error;
    int retryct;

    Options = (struct rbf_opt *)&(pathd→path.fm_opt);
    DTableE = pathd→path.fm_pvt.rbf.pd_dtb;

    switch(Code){
        case SS_DCmd:
            if((Error = Cond_InitDrive(DevStatics,                      /* pg. 447 */
                    Options, DTableE, SysGlobs)) != 0)
                return Error;
            return direct_command(regs, procd, Options, DevStatics);    /* pg. 466 */
        case SS_Reset:
            if((Error = Cond_InitDrive(DevStatics,                      /* pg. 447 */
                    Options, DTableE, SysGlobs)) != 0)
                return Error;
            for(retryct = 2; retryct != 0; retryct−−){
                SETUP_CMD(DevStatics→V_CDB,
                        SCSI_REZERO_UNIT, 0, 0);
                DevStatics→v_Bytes = 0;
                ClaimController(DevStatics→EvID);                       /* pg. 479 */
                Error = Exec(REZERO_CMD_LEN, 0, (u_int32 *)0,           /* pg. 456 */
                        Options→pd_ctrlrid,
                        DevStatics);
                ReleaseController(DevStatics→EvID);                     /* pg. 479 */
                if(Error == 0)
                        return 0;
                if(Error == E_DIDC)
                    InitDrive((Board)DevStatics→v_sysio.v_port,         /* pg. 448 */
                                    (Options→pd_cntl & CNTL_NOFMT) != 0,
                                    (Options→pd_scsiopt & SCSI_PARITY) != 0,
                                    &(Options→pd_ssize),
                                    Options→pd_ctrlrid,
                                    DevStatics,
                                    (void **)&(DTableE→v_sczero),
                                    &(DTableE→v_init),
                                    &(DTableE→v_dtext),
                                    SysGlobs);
            }
            return Error;
        case SS_WTrk:
            if((Options→pd_cntl & CNTL_NOFMT) != 0)
                return E_FORMAT;
            if((regs→d[2] != (unsigned int)Options→pd_toffs) ||
                    (((regs→d[3] >> 8) & 0x0ff) != 0))
                /*Ignore write tracks for non-cyl 0 head 0 */
                return 0;
            if((Error = InitDrive((Board)DevStatics→v_sysio.v_port,              /* pg. 448 */
                    (Options→pd_cntl & CNTL_NOFMT) != 0,
                    (Options→pd_scsiopt & SCSI_PARITY) != 0,
                    &(Options→pd_ssize),
                    Options→pd_ctrlrid,
                    DevStatics,
                    (void **)&(DTableE→v_sczero),
                    &(DTableE→v_init),
                    &(DTableE→v_dtext),
                    SysGlobs)) != 0)
                return Error;
            DTableE→v_zerord = FALSE;
            DTableE→v_init = FALSE;
            if((Error = SetSectorSize(DevStatics,
                    (int)Options→pd_ctrlrid,
                    (int)Options→pd_ssize)) != 0)
                return Error;
            DevStatics→V_CDB[0] = SCSI_FORMAT_UNIT;
            DevStatics→V_CDB[1] = 0;
            DevStatics→V_CDB[2] = 0;
            DevStatics→V_CDB[3] = 0;
            DevStatics→V_CDB[4] = regs→d[4];
            DevStatics→V_CDB[5] = 0;
            ClaimController(DevStatics→EvID);                                    /* pg. 479 */
            Error = Exec(FORMAT_CMD_LEN, 0, (u_int32 *)0,                         /* pg. 456 */
                    Options→pd_ctrlrid, DevStatics);
            ReleaseController(DevStatics→EvID);                                  /* pg. 479 */
            return Error;
        default:
            return E_UNKSVC;
    }
}


int DSize(MyStatics DevStatics, struct rbf_opt *Options, REGISTERS *regs)
{
    u_int32 Sectors;
    ushort SectSize=0;
    int Errno;

    if((Errno = GetCapacity(DevStatics→EvID,                              /* pg. 449 */
            (Options→pd_cntl & CNTL_NOFMT) != 0,
            &SectSize, &Sectors, Options→pd_ctrlrid,
            DevStatics)) != 0)
        return Errno;
    regs→d[2] = Sectors;
    return 0;
}
```

30.2.6 IRQ Service

```
#include <rbf.h>
#include "drvr.h"

int C_IRQRtn(MyStatics DevStatics, Board port)
{
    register ushort process;

    if((process = DevStatics→v_sysio.v_wake) == 0)
        return −1;          /*Not our interrupt */
    if(port→BD_STATUS >0)
        return −1;          /*Not our interrupt */

    /*Is our interrupt */
    port→BD_CONTROL = 0;            /*Disable interrupts from the board */
    DevStatics→v_sysio.v_wake = 0;  /*We are responsible for waking this process */
    AWake(process);                                                     /* pg. 475 */
    return 0;
}
```

30.3 Drive Management

30.3.1 Read Sector 0

```
#include "drvr.h"
```

```
ReadSector0(u_int32 Block, MyStatics DevStatics,
        u_char *Buffer, Rbfdrive DTableE, struct rbf_opt *Options)
{
    register u_int32 *lptr, *lptr2, *limit;
    u_int32 Sectors;
    int Error = 0;


    if(DTableE→v_zerord != FALSE){          /*sector 0 already read */
        /*Just copy data out of sector 0 buffer */
        lptr = (u_int32 *)Buffer;
        limit = (u_int32 *)((uchar *)lptr + Options→pd_ssize);
        lptr2 = (u_int32 *)DTableE→v_sczero;
        while(lptr != limit)
            *lptr++ = *lptr2++;
        return 0;
    }
    if((Error = BaseRead(1, Block, (uchar *)Buffer, Options, DevStatics)) == 0){  /* pg. 439 */
        if(((Options→pd_typ & TYP_HARD) != 0) &&
                ((Options→pd_typ & TYP_HREMOV) == 0)){
            DTableE→v_zerord = TRUE;
            lptr = (u_int32 *)Buffer;
            limit = (u_int32 *)((u_char *)lptr + Options→pd_ssize);
            lptr2 = (u_int32 *)DTableE→v_sczero;
            while(lptr != limit)
                *lptr2++ = *lptr++;
        }
        /*
            Initialize the drive table from the buffer
        */
        MoveData(DTableE, Buffer, 21);                              /* pg. 473 */
        /*
            Validate the disk format and make certain it is compatible with this
            hardware.
        */
        if((Error = GetCapacity(DevStatics→EvID, TRUE,              /* pg. 449 */
                &(Options→pd_ssize),
                &Sectors, Options→pd_ctrlrid,
                DevStatics)) != 0)
            return Error;;

        return BoundsCheck(Block, DTableE→v_0.dd_tot[2] +           /* pg. 456 */
                256 * (DTableE→v_0.dd_tot[1] +
                256 * DTableE→v_0.dd_tot[0]), Sectors,
                FALSE);
    }else
        return Error;
}
```

30.3.2 Initialize a Drive

```
#include <types.h>
#include <rbf.h>
#include <errno.h>
#include "drvr.h"
#include "lowlevel.h"
#define NOTRDY_TO               10          /*Not ready timeout value */

void ResetQ(Board, boolean, u_int32);

int Cond_InitDrive(MyStatics DevStatics, struct rbf_opt *Options,
Rbfdrive DTableE, void *SysGlobs)
{
    if((Options→pd_drv >= DevStatics→v_ndrv) ||
            (Options→pd_lun > MAXLUN) ||
            (Options→pd_ctrlrid > MAXSCSI))
        return E_UNIT;                  /*bad unit number */

    if(DTableE→v_init == FALSE)
        return InitDrive((Board)DevStatics→v_sysio.v_port,              /* pg. 448 */
                (Options→pd_cntl & CNTL_NOFMT) != 0,
                (Options→pd_scsiopt & SCSI_PARITY) != 0,
                &(Options→pd_ssize),
                Options→pd_ctrlrid,
                DevStatics,
                (void **)&(DTableE→v_sczero),
                &(DTableE→v_init),
                &(DTableE→v_dtext),
                SysGlobs);
    if(Options→pd_ssize == 0)
        Options→pd_ssize = DTableE→v_dtext;
    return 0;
}

/*
    The init() function initialized the 33C93A and the entire drive table.
    This function initializes a specific drive attached to the 33C93A and
    some data structures associated with that specific drive.
*/
```

```
int InitDrive(Board port, boolean NoFmt, boolean Parity, u_int16 *SectSize,
        u_char ctrlrid,
        MyStatics DevStatics, void **DTv_sczero, u_char *DTv_init,
        u_int32 *DTv_ext, void *SysGlobs)
{
    int Errno;
    u_int32 Sectors;
    int Retries;

    for(Retries = RETRY_MAX; Retries >=0; −−Retries){
        ResetQ(port, Parity, DevStatics→EvID);                    /* pg. 449 */

        if((Errno = Make_UnitReady(DevStatics→EvID, ctrlrid,      /* pg. 449 */
                DevStatics)) == 0)
            Errno = GetCapacity(DevStatics→EvID, NoFmt,           /* pg. 449 */
                SectSize, &Sectors, ctrlrid,
                DevStatics);
        switch(Errno){
            case E_DIDC:
                continue;
            case E_HARDWARE:
                ClaimController(DevStatics→EvID);                 /* pg. 479 */
                BdReset(port, SysGlobs);                          /* pg. 460 */
                Errno = Init33C93A(port, Parity);                 /* pg. 436 */
                ReleaseController(DevStatics→EvID);               /* pg. 479 */
                if(Errno != 0)
                    return Errno;
                continue;
            case 0:
                break;
            default:
                return Errno;
        }
        break;
    }
    /*Allocate the sector zero buffer */
    if(*DTv_sczero == (void *)0){
        if((*DTv_sczero = (void *)_srqmem(*SectSize)) == (void *)−1){   /* pg. 472 */
            *DTv_sczero = (void *)0;
            return E_NORAM;
        }
        *DTv_ext = *SectSize;
    }
    *DTv_init = TRUE;
    return 0;
}


/*
    Has a SCSI reset happened? If it has, reset the 33c93.
*/
void ResetQ(Board port, boolean Parity, u_int32 Event)
{
    ClaimController(Event);                                      /* pg. 479 */
    if(port→BD_STATUS <0){          /*An unexplained interrupt */
            if((GET_SCSI_STATUS(port) & 0xf0) == 0)
                Init33C93A(port, Parity);                        /* pg. 436 */
    }
    ReleaseController(Event);                                    /* pg. 479 */
}


int Make_UnitReady(u_int32 Event, u_char SCSI_ID, MyStatics DevStatics)
{
    ushort TimeCtr;
    int Errno;

    SETUP_CMD(DevStatics→V_CDB, SCSI_TEST_UNIT_READY, 0, 0);
    TimeCtr = NOTRDY_TO;
    do{
        DevStatics→v_Bytes = 0;
        ClaimController(Event);                                  /* pg. 479 */
        Errno = Exec(READY_CMD_LEN, WD_DPD_In, (u_int32 *)0,     /* pg. 456 */
                SCSI_ID, DevStatics);
        ReleaseController(Event);                                /* pg. 479 */
    }while((Errno != 0) && (TimeCtr–– != 0));
    return Errno;
}

int GetCapacity(u_int32 Event, boolean NoFmt, u_int16 *SectSize,
u_int32 *Sectors, u_char ctrlrid, MyStatics DevStatics)
{
    struct {
        ulong Size;
        ulong SSize;
    }RCData;
    int Errno;

    SETUP_CMD_10(DevStatics→V_CDB, SCSI_READ_CAPACITY, 0, 0, 0);
    DevStatics→v_Bytes = sizeof(RCData);
    ClaimController(Event);                                  /* pg. 479 */
    Errno = Exec(READCAP_CMD_LEN, WD_DPD_In, (u_int32 *)&RCData,/* pg. 456 */
            ctrlrid, DevStatics);
    ReleaseController(Event);                                /* pg. 479 */
    if(Errno != 0)
        return Errno;
    *Sectors = RCData.Size;

    if(*SectSize == 0)
        *SectSize = RCData.SSize;
    else if(NoFmt){/*Format protected */
        if(*SectSize != RCData.SSize) /*Mismatch */
            return E_SECTSIZE;
    }else /*Format enabled */
        if(*SectSize != RCData.SSize) /*Mismatch */
            /*Change the sector size */
            return SetSectorSize(DevStatics, ctrlrid,        /* pg. 451 */
                    *SectSize);

    return 0;
}
```

30.3.3 Set Sector Size

```
#include "drvr.h"

typedef struct {
    uchar length;
    uchar type;
    unsigned wp                  :1;
    unsigned res1                :7; /*reserved */
    uchar block_desc_length;
    /*Block descriptor */
    uchar density_code;
    unsigned blocks              :24;
    uchar res2;
    unsigned block_length        :24; /*logical block length */
}block_desc_type;



typedef struct {
    block_desc_type hdr;
    unsigned parameter_savable          :1;
    unsigned reserved                   :1;
    unsigned page_code                  :6;
    uchar page_length;
    ushort tracks_per_zone,
            alternate_sectors_per_zone,
            alternate_tracks_per_zone,
            alternate_tracks_per_vol,
            sectors_per_track,
            bytes_per_sector,               /*Physical block length */
            interleave,
            track_skew,
            cylinder_skew;
    unsigned dt_ssec                    :1,         /*Drive type bits */
            dt_hsec                     :1,
            dt_rmb                      :1,
            dt_surf                     :1,
            dt_ins                      :1,
                                        :27;
}page3_type;


/*
    Profiles
*/
void init_blk_header(block_desc_type *, int );
int GetChangeable(void *, int, MyStatics, int);
int GetMode(void *, int, MyStatics, int);
int mode_set(void *, int, MyStatics, int);


int SetSectorSize(MyStatics DevStatics, u_char SCSI_ID, u_int16 sector_size)
{
    int error;
    union {
        page3_type page3;
        block_desc_type block_desc;
    }status_info;
    int set_length;

    if((error = GetChangeable((void *)&status_info, sizeof(status_info),        /* pg. 452 */
            DevStatics,
            SCSI_ID)) != 0)
        return error;
    if(status_info.page3.bytes_per_sector != 0){
        if((error = GetMode((void *)&status_info, sizeof(status_info),        /* pg. 453 */
                DevStatics, SCSI_ID)) != 0)
            return error;
        status_info.page3.bytes_per_sector = sector_size;
        status_info.page3.sectors_per_track = 0; /*drive will set */
        status_info.page3.parameter_savable = 0;
        status_info.page3.reserved = 0;
        set_length = sizeof (page3_type);
    }else
        set_length = sizeof (block_desc_type);

    init_blk_header(&status_info.block_desc, sector_size);                 /* pg. 452 */
    return mode_set((void *)&status_info, set_length, DevStatics,          /* pg. 453 */
            SCSI_ID);
}

void init_blk_header(block_desc_type *status_info, int blk_size)
{
    status_info→length = 0;
    status_info→type = 0;
    status_info→wp = 0;
    status_info→res1 = 0;
    status_info→block_desc_length = 8;
    status_info→density_code = 0;
    status_info→blocks = 0;
    status_info→res2 = 0;
    status_info→block_length = blk_size;
}


int GetChangeable(void *data, int datasize, MyStatics DevStatics, int SCSI_ID)
{
    register struct cdb1 {
        uchar cmd;
        unsigned lun            :3,
                res1            :5,
                pcf             :2,
                code            :6;
        uchar res2;
        uchar allocation_length;
        unsigned res3           :6,
                flag            :1,
                link            :1;
    }*CDB = (struct cdb1 *)DevStatics→V_CDB;
    CDB→cmd = SCSI_MODE_SENSE;
    CDB→flag = CDB→link = CDB→lun = CDB→res1 = CDB→res2 = CDB→res3 = 0;
    CDB→pcf = 1;          /*this is the magic number for return changeable */
    CDB→code = 3;         /*Page 3 is format parameters */
    CDB→allocation_length = 36;
    DevStatics→v_Bytes = datasize;
    return Exec(sizeof(*CDB), WD_DPD_In, (u_int32 *)data,              /* pg. 456 */
            (uchar)SCSI_ID, DevStatics);
}

int GetMode(void *data, int datasize, MyStatics DevStatics, int SCSI_ID)
{
    register struct cdb2 {
        uchar cmd;
        unsigned lun                :3,
                res1                :5,
                pcf                 :2,
                code                :6;
        uchar res2;
        uchar allocation_length;
        unsigned res3               :6,
                flag                :1,
                link                :1;
    }*CDB = (struct cdb2 *)DevStatics→V_CDB;
    CDB→cmd = SCSI_MODE_SENSE;
    CDB→flag = CDB→link = CDB→lun = CDB→res1 = CDB→res2 = CDB→res3 = 0;
    CDB→pcf = 0;          /*this is the magic number for return current values */
    CDB→code = 3;         /*Page 3 is format parameters */
    CDB→allocation_length = 36;
    DevStatics→v_Bytes = datasize;
    return Exec(sizeof(*CDB), WD_DPD_In, (u_int32 *)data, (uchar)SCSI_ID, /* pg. 456 */
            DevStatics);
}


int mode_set(void *data, int set_length, MyStatics DevStatics, int SCSI_ID)
{
    register struct cdb3 {
        uchar cmd;
        unsigned lun                :3,
                pf                  :1,
                res1                :3,
                smp                 :1;
        ushort res2;
        uchar param_length;
        unsigned res3           :6,
                flag            :1,
                link            :1;
    }*CDB = (struct cdb3 *)DevStatics→V_CDB;
    CDB→cmd = SCSI_MODE_SELECT;
    CDB→smp = 1;
    CDB→link = CDB→lun = CDB→res1 = CDB→res2 = CDB→res3 = 0;
    CDB→pf = 0;
    CDB→param_length = set_length;
    DevStatics→v_Bytes = set_length;
    return Exec(sizeof(*CDB), WD_DPD_Out, (u_int32 *)data, (uchar)SCSI_ID, /* pg. 456 */
            DevStatics);
}
```

30.4 Miscellaneous

```
#include <rbf.h>
#include <errno.h>
#include "drvr.h"


/*
    Return an event ID number for the event corresponding to this
    port/SCSI_ID. The event will be made if it does not exist. return
    −1 if there is an error.
    Use Microware naming conventions for port event: <c><portaddress>
    This event claims the entire controller, so the SCSI ID suffix is not
    required.
    Convention is <c> = 'i' for interrupt service events. This is a non
    interrupt service mutex event for locking the controller, so we invent
    the convention that <c> = 'c' for controller locking.
*/

/*
    Profiles
*/
void MakeEvName(char *, u_int32);

u_int32 MakeEvent(u_int32 port, int *Errno)
{
    char EvName[10];
    u_int32 EventID;
    MakeEvName(EvName, port);                                    /* pg. 455 */

    if((EventID = _Ev_link(EvName)) == −1)                       /* pg. 474 */
        return(_Ev_Creat(EvName, Errno));                        /* pg. 474 */
    else
        return EventID;
}


void MakeEvName(char *EvName, u_int32 port)
{
    register int i;
    extern int HexTbl();

    EvName[0] = 'c';
    EvName[9] = '\0';
    for(i=8; i != 0; i−−){
        EvName[i] = ((char *)HexTbl)[port & 0x0f];
        port >>= 4;
    }
}

void DeleteEvent(u_int32 port, u_int32 EvID)
{
    char EvName[10];

    MakeEvName(EvName, port);                                    /* pg. 455 */
    _Ev_Unlink(EvID);                                            /* pg. 474 */
    _Ev_Del(EvName);                                             /* pg. 474 */
}


u_int32 addoffsets(u_int32 Sector, u_int32 lsnoffset, boolean AutoSize,
        u_char TrackOffset, u_int16 T0Sects, u_int16 SectPerTrack,
        u_char Sides)
{
    Sector += lsnoffset;
    if(!AutoSize && (TrackOffset != 0)){
        Sector += T0Sects;          /*Sectors on track 0 side 0 */
        Sector += (SectPerTrack * (Sides − 1));        /*Rest of sectors on track 0 */
        Sector += (TrackOffset − 1) * Sides * SectPerTrack;
    }
    return Sector;
}
```

```
int BoundsCheck(u_int32 lsn, int ct, int high, boolean OverMaxCt)
{
    if(OverMaxCt)
        /*Not what this is meant for, but there's no better error */
        return E_PARAM;
    if(ct + lsn > high)
        return E_SECT;
    return 0;
}
```

30.5 SCSI Management

```
#include <rbf.h>
#include "drvr.h"
#include "lowlevel.h"

int Exec(int Len, u_char Direction, u_int32 *Buffer,
        u_char SCSI_ID, MyStatics DevStatics)
{
    register Board port;
    register int i;
    int Errno;

    port = (Board)DevStatics->v_sysio.v_port;

    /*First move any data to the I/O board that will be written */

    if((DevStatics->v_Bytes >0) && (Direction == WD_DPD_Out)){
        port->BD_Address = BD_PUBLIC_BUF;
        if((((ulong)Buffer & 0x02) == 0) &&          /*addr is multiple of 4 */
        ((DevStatics->v_Bytes & 0x03) == 0)){         /*So is length */
            register ulong *lptr, *limit;
            lptr = (ulong *)Buffer;
            limit = (ulong *)((uchar *)lptr + DevStatics->v_Bytes);
            while(lptr != limit)
                port->Databuffer.L_DataBuf = *lptr++;
        }else {/*Multiple of two */
            register u_int16 *sptr, *limit;
            sptr = (u_int16 *)Buffer;
            limit = (u_int16 *)((uchar *)sptr + DevStatics->v_Bytes);
            while(sptr != limit)
                port->Databuffer.W_DataBuf = *sptr++;
        }
```

```
}

/*
    Then do the I/O operation with retries if required.
*/
while(TRUE){
    port→WD_SELECT = WD_CDB1;
    for(i = 0 ; i <Len ; ++i)
        port→WD_WRITE_REG = DevStatics→V_CDB[i];
    /*Fill the rest of the CDB registers */
    Errno = 0;
    for(;i<10;++i)
        port→WD_WRITE_REG = Errno;

    Set_XFrCt(port, DevStatics→v_Bytes);                          /* pg. 459 */

    SET_TARGET(port, SCSI_ID | Direction);

    while(TRUE){
        port→BD_Address = BD_PUBLIC_BUF;
        DevStatics→v_sysio.v_wake = DevStatics→v_sysio.v_busy;
        BD_EnableInt(port);                                       /* pg. 481 */
        SET_CMD(port, SCSI_X_SAT);        /*Select and transfer */
        do{
            dosleep(0);                                           /* pg. 475 */
        }while(DevStatics→v_sysio.v_wake != 0);

        if((Errno = GET_SCSI_STATUS(port)) != WD_SAT_OK)
            if((Errno = SAT_Error(Errno, port,                    /* pg. 460 */
                    DevStatics)) == 0)
                /*SAT_Error() wants a retry */
                continue;
            else
                return Errno;
        else
            break;
    }
    Errno = GET_SCSI_TARGETSTAT(port);
    if(Errno == 0)
        break;        /*Break out of while(TRUE) loop */
    else {
        if((Errno & 0x02) != 0)
            if((Errno = DeviceCheck(DevStatics, SCSI_ID)) != 0)  /* pg. 462 */
                return Errno;
        if((Errno & 0xC0) != 0){        /*Busy or reservation conflict */
```

```
                dosleep(0x8000007f);        /*wait about .5 seconds */              /* pg. 475 */
                continue;           /*and retry */
            }
        }
    }

    /*Copy any data that was read */

    if((DevStatics→v_Bytes >0) && (Direction == WD_DPD_In)){
        /*Move data from board */
        port→BD_Address = BD_PUBLIC_BUF;
        if((((ulong)Buffer & 0x02) == 0) &&         /*Addr is multiple of 4 */
                ((DevStatics→v_Bytes & 0x03) == 0)){        /*So is length */
            register u_int32 *lptr, *limit;
            lptr = (u_int32 *)Buffer;
            limit = (u_int32 *)((uchar *)lptr + DevStatics→v_Bytes);
            while(lptr != limit)
            *lptr++ = port→Databuffer.L_DataBuf;
        }else {                     /*Multiple of two */
            register u_int16 *sptr, *limit;
            sptr = (ushort *)Buffer;
            limit = (u_int16 *)((uchar *)sptr + DevStatics→v_Bytes);
            while(sptr != limit)
                *sptr++ = port→Databuffer.W_DataBuf;
        }
    }
    return 0;
}

#include "drvr.h"
#include <errno.h>

#define RESET_LOOPS                 256*10      /*10 seconds */
#define RESET_DELAY                 0x80000001      /*1/256 second */

void LL_Put(Board port, u_char value, u_char reg)
{
    port→WD_SELECT = reg;           /*Select register */
    nop();
    port→WD_WRITE_REG = value;
}



int LL_Get(Board port, u_char reg)
```

```
{
    port→WD_SELECT = reg;
    nop();
    return (port→WD_READ_REG);
}


/*
    The value returned from a successful Do_WD_Reset should be
    0x00000001 "The device has successfully completed a reset com-
    mand..." A value of −1 signifies that it timed out.
*/
int Do_WD_Reset(Board port)
{
    int ctr;
    LL_Put(port, WD_RESET, WD_CMDREG);          /*Start a 33C93A reset */ /* pg. 458 */

    for(ctr= 0; ctr < RESET_LOOPS; ++ctr)
        if((port→BD_STATUS & 0x80) != 0)
            /*Reset is done */
            return(LL_Get(port, WD_SCSI_STAT));          /*Touch SCSI status */ /* pg. 458 */
        else
            dosleep(RESET_DELAY);                                      /* pg. 475 */
    return −1;
}

void Set_Control(Board port, u_char value)
{
    LL_Put(port, value, WD_CONTROL);                                   /* pg. 458 */
    /*Register auto-increments */
    port→WD_WRITE_REG = WD_TIMEOUT;
}


void Set_XFrCt(Board port, u_int32 value)
{
    port→WD_SELECT = WD_XFRCT1;
    port→WD_WRITE_REG = ((value >>16) & 0x0ff);
    port→WD_WRITE_REG = ((value >> 8) & 0x0ff);
    nop();
    port→WD_WRITE_REG = value & 0x0ff;
}


int Get_XFrCt(Board port)
```

```
{
    register int accum;
    port→WD_SELECT = WD_XFRCT1;
    accum = port→WD_READ_REG;
    accum <<= 8;
    accum += port→WD_READ_REG;
    accum <<= 8;
    accum += port→WD_READ_REG;
    return accum;
}


/*reset the controller and the SCSI bus */
void BdReset(Board port, void *SysGlobs)
{
    register uchar zero=0;

    port→BD_CONTROL = BD_RESET;
    dosleep(0x80000000 | 5);        /*Wait about .02 seconds */             /* pg. 475 */
    port→BD_CONTROL = zero;         /*Stop resetting. Leave interrupts off */
}


_asm("nop: nop");
_asm(" rts");
```

30.5.1 Error Handling

```
#include <rbf.h>
#include <errno.h>
#include "drvr.h"
#include "lowlevel.h"
/*
    A SCSI protocol error caused a command failure. The error code is in
    Errno.
*/

int SAT_Error(int Errno, Board port, MyStatics DevStatics)
{
    int Count;

    switch(Errno & 0x0f0){
        case 0x040: /*Status group 4 */
```

```
/*
    The command terminated prematurely due to an error or other unex-
    pected condition. Now we try to find a way to restart the command.
*/
switch(Errno & 0x0f){
    case 0: /*Invalid command */
        break;
    case 1: /*Unexpected disconnect by the target */
        break;
    case 2: /*A timeout during (re)select */
        return E_NOTRDY;
    case 3: /*Parity error */
        break;
    case 4: /*Parity error with ATN asserted */
        break;
    case 5: /*Sector number off disk */
        break;
    case 6: /*WD33C93A in non-advanced mode */
        break;
    case 7: /*Incorrect status byte was received */
        break;
        /*
            The following cases are all in a family with values depending on which
            phase got the error.
        */
        /*
            An unexpected information phase was requested.
        */
    case 8: /*Data out phase] */
        break;
    case 9: /*[Data in phase ] */
        break;
    case 10: /*[Command phase] */
        break;
    case 11: /*[Status phase] */
        /*Reselect and transfer */
        /*
            Resume after the data phase has been completed.
        */
        SET_CMDPHASE(port, (uchar)0x046);
        Count = Get_XFrCt(port);                                /* pg. 459 */
        /*Calculate amount left */
        DevStatics→v_Bytes −=Count;
        Set_XFrCt(port, (ulong)0);                              /* pg. 459 */
        return 0; /*Zero means try to continue */
```

```
                case 12: /*[Unspecified info out phase] */
                    break;
                case 13: /*[Unspecified info in phase] */
                    break;
                case 14: /*[Message out phase] */
                    break;
                case 15: /*[Message in phase] */
                    break;
                default:
                    break;
            }
        case 0x020: /*Status group 2 */
            break;
        default:
            break;
    }
    /*
        There's no way to deal with this error so return this useless error code
    */
    return E_HARDWARE;
}


/*
    A device error caused a SCSI command failure The device error code
    is in Errno.
*/
int DeviceCheck(MyStatics DevStatics, u_char SCSI_ID)
{
    struct {
        unsigned validity           :1,
                Class               :3,
                                    :4,
                Segment_Num         :8,
                FileMark            :1,
                EOM                 :1,
                ILI                 :1,
                                    :1,
                Sense_Key           :4;
        uchar InfoByte[4];
        uchar AdditionalLength;
        uchar Reserved[4];
        uchar ErrorCode;
        uchar Reserved2;
        uchar FRUCode;
        unsigned FPV                :1,
            CD              :1,
                            :2,
            BPV             :1,
            BitPtr          :3;
        uchar FieldPtr[2];
    }Req_Sense_Return;

    if(DevStatics→V_CDB[0] == SCSI_REQUEST_SENSE)
        /*Don't recurse */
        return E_HARDWARE;

    SETUP_CMD(DevStatics→V_CDB, SCSI_REQUEST_SENSE, 0, 18);
    DevStatics→v_Bytes = sizeof(Req_Sense_Return);

    if(Exec(SENSE_CMD_LEN, WD_DPD_In,                          /* pg. 456 */
            (u_int32 *)&Req_Sense_Return, (u_char)SCSI_ID, DevStatics) != 0)
        return E_HARDWARE;

    switch(Req_Sense_Return.Sense_Key){
        case 0:
            return 0;
        case 1: /*Recovered error */
            return 0; /*Happy */
        case 2: /*Not ready */
            switch(Req_Sense_Return.ErrorCode){
                case 4: /*not ready */
                    return E_NOTRDY;
                case 0x44: /*Internal controller error */
                    return E_HARDWARE;
                default: /*Mystery: return real data */
                    return ((Req_Sense_Return.Sense_Key <<8) |
                        Req_Sense_Return.ErrorCode);
            }
        case 3: /*Medium error */
            switch(Req_Sense_Return.ErrorCode){
                case 0x10: /*ID CRC or ECC error */
                case 0x12: /*No address mark in ID field */
                case 0x13: /*No address mark in data field */
                case 0x14: /*No record found */
                case 0x15: /*Seek error */
                    return E_SEEK;
                case 0x11: /*Uncorrectable data error */
                    return E_READ;
                case 0x19: /*Defect list error */
                case 0x1c: /*Primary defect list missing */
                    return E_READ;
                case 0x31: /*Medium format corrupted */
                    return E_BTYP;
                case 0x32: /*No defect spare available */
                    return E_FULL;
                default: /*Mystery: return real data */
                    return ((Req_Sense_Return.Sense_Key <<8) |
                        Req_Sense_Return.ErrorCode);
            }
        case 4: /*Hardware error */
            switch(Req_Sense_Return.ErrorCode){
                case 1: /*No index from drive */
                    return E_NOTRDY; /*Say not ready */
                case 2: /*No seek complete */
                case 0x10: /*ID CRC or ECC error */
                case 0x15: /*Seek error */
                    return E_SEEK;
                case 3: /*Write fault received from drive */
                    return E_WRITE;
                case 8: /*LUN communication failure */
                case 9: /*Track following error */
                case 0x40: /*RAM failure */
                case 0x41: /*Data path diagnostic failure */
                case 0x42: /*Power-on diagnostic failure */
                case 0x44: /*Internal controller error */
                case 0x47: /*SCSI interface parity error */
                    return E_HARDWARE;
                default: /*Mystery: return real data */
                    return ((Req_Sense_Return.Sense_Key <<8) |
                        Req_Sense_Return.ErrorCode);
            }
        case 5: /*Illegal request */
            switch(Req_Sense_Return.ErrorCode){
                case 0x20: /*Invalid command code */
                case 0x22: /*Illegal function for drive type */
                    return E_BTYP;
                case 0x21: /*Illegal logical block address */
                    return E_SECT;
                case 0x24: /*Illegal field in CDB */
                case 0x26: /*Invalid field in param list */
                    return E_PARAM;
                case 0x25: /*Invalid LUN */
                    return E_UNIT;
                default: /*Mystery: return real data */
                    return ((Req_Sense_Return.Sense_Key <<8) |
                    Req_Sense_Return.ErrorCode);
            }
        case 6: /*Unit attention */
            return E_DIDC; /*Always treat as disk ID change */
        case 11: /*Aborted command */
            switch(Req_Sense_Return.ErrorCode){
                case 0x43: /*Message reject error */
                case 0x45: /*Select/reselect failed */
                case 0x48: /*Initiator detected error */
                case 0x49: /*Inappropriate/illegal message */
                    return E_DEVBSY;
                default: /*Mystery: return real data */
                    return ((Req_Sense_Return.Sense_Key <<8) |
                        Req_Sense_Return.ErrorCode);
            }
        case 13: /*Volume overflow */
            return E_FULL;
        case 14: /*Data miscompare */
            return E_WRITE;
        default:
            return ((Req_Sense_Return.Sense_Key <<8) |
                Req_Sense_Return.ErrorCode);
    }
}
```

30.6 Direct Command Interface

This function implements the SCSI direct command setstat and getstat functions. The function checks its parameters extensively. This is required because IOMan cannot validate parameters for new getstat and setstat functions. Direct_command() validates parameters as follows:

- Can the caller read the data pointed to by A0?
- Are the file manager code, device code, and command sync code specified in the direct command block correct?
- Is the caller in group 0?
- Are all the other pointer parameters valid?

```
#include <errno.h>
#include <modes.h>
```

```
#include "drvr.h"
#include "dcmd.h"

#define SENSE_LEN 6


int direct_command(REGISTERS *regs, procid *procd,
struct rbf_opt *Options, MyStatics DevStatics)
{
    register Dcmd dcmd; /*direct command structure */
    register Cmdblk cmd;
    int i;
    int Errno;
    register uchar *ptr;

    dcmd = regs→a[0];
    /*Is dcmd a valid pointer? */
    if(_chkMem(sizeof(struct d_cmd), S_IREAD, dcmd, procd))          /* pg. 476 */
        return E_PERMIT;
    cmd = (Cmdblk)dcmd→dcmdblk;
    /*
        Preliminary checks.
    */
    if((dcmd→manager != Options→pd_dtp) ||
            (dcmd→device != SCSIdevice) ||
            (dcmd→dcmdsync != DCMDSYNC))
        return E_PARAM;
    /*
        The constants seem correct. Now make certain that the caller is in the
        super group.
    */
    if(procd→_group != 0)
        return E_PERMIT;
    /*
        Now check the other pointers.
    */
    if(_chkMem(sizeof(struct cmdblk), S_IREAD | S_IWRITE, cmd, procd))    /* pg. 476 */
        return E_PERMIT;
    if(_chkMem(cmd→_cb_cmdlen, S_IREAD | S_IWRITE, cmd→_cb_cmdptr, procd))
        return E_PERMIT;
    if(cmd→_cb_datlen) /*Will data be transferred? */
        if(_chkMem(cmd→_cb_datlen, S_IREAD | S_IWRITE, cmd→_cb_datptr, procd))
            return E_PERMIT;
    if(cmd→_cb_errlen) /*Is there an error block? */
        if(_chkMem(cmd→_cb_errlen, S_IWRITE, cmd→_cb_errptr, procd))
        return E_PERMIT;
    /*More parameter checking */
    if((cmd->_cb_cmdlen != 6) && (cmd->_cb_cmdlen != 10))
        return E_PARAM;
    if((cmd->_cb_xfer != INPUT) && (cmd->_cb_xfer != OUTPUT))
        return E_PARAM;
    /*
        Fill in values to be returned in the cmd block
    */
    cmd->_cb_pd_lun = Options->pd_lun;
    cmd->_cb_scsi_id = Options->pd_ctrlrid;
    for(i=0, ptr=cmd->_cb_cmdptr;i<cmd->_cb_cmdlen;++i)
        DevStatics->V_CDB[i] = *(ptr++);
    DevStatics->V_CDB[1] = Options->pd_lun << 5;
    DevStatics->v_Bytes = cmd->_cb_datlen;
    Errno = Exec(cmd->_cb_cmdlen, (cmd->_cb_xfer == INPUT) ?          /* pg. 456 */
            WD_DPD_In : WD_DPD_Out,
            cmd->_cb_datptr,
            Options->pd_ctrlrid,
            DevStatics);
    if((Errno != 0) && (cmd->_cb_errlen != 0)){
        SETUP_CMD(DevStatics->V_CDB, SCSI_REQUEST_SENSE, 0, cmd->_cb_errlen);
        DevStatics->v_Bytes = cmd->_cb_errlen;
        Exec(SENSE_LEN, WD_DPD_In, cmd->_cb_errptr,                 /* pg. 456 */
                Options->pd_ctrlrid, DevStatics);
    }
    return Errno;
}
```

30.7 Assembly Language Glue

This assembly language is the "glue" that lets a C program fit into the interfaces designed for an assembly language driver. It replaces cstart and any functions that might possibly use static storage.

C-language system code can use the static storage class, but I think it is a dangerous practice. The C compiler makes no guarantees about how it will arrange static variables. It happens to leave the variables in device static storage in the order they are declared, but it may not always do that. I prefer to avoid static variables and pass device static storage around as a pointer to a structure (which C will not reorder). I make certain that no static data crept into the driver by inspecting the output of ***rdump*** for each .r file in the driver and each library function the driver invokes.

Device drivers written in C tend to use too much stack space. This causes nasty and sometimes non-obvious system crashes, so I allocate a large stack just for this drive. Since only one process at a time can use a device static storage for an RBF driver,[1] I leave space for the stack in device static storage. Each call to the driver moves to the driver's stack on entry and moves back to its original stack when it leaves the driver.

```
          *****************************
          *
          * cstart.a - C program startup routine for a device driver
          *
00000001  Edit      equ     1

                    use     <oskdefs.d>
                    opt     -l
00000001  Carry:    equ     %00000001 Carry bit

0000000e  Typ       equ     Drivr
00001000  Stk       equ     4096            Memory size
00000101  Cerror    equ     257             arbitrary C error

                    psect   drmain_a,(Typ<<8)!Objct,((ReEnt+SupStat)<<8)!1,Edit,0,_Entry

c0dee0e0  Sflag     equ     $C0DEE0E0


          * NEWSTACK clobbers d1 and a3
          NEWSTACK macro
          *
          * Move the stack
                    move.l  a2,a3
                    add.l   #Stk-1,a2       Get the address of the end of the stack.
                    move.l  sp,–(a2)        Put old stack address on the new stack
                    move.l  a2,sp           The actual stack switch
                    move.l  a3,a2
                    endm

          OLDSTACK macro
                    move.l  (sp)+,sp        old sp
                    endm

00000000            align
          *
          * C Program entry point
          *
```

[1] RBF locks device static storage before every call to the driver, but SCF leaves device static storage unlocked for getstat calls to the driver. Although the outline of this RBF driver is generally usable for SCF drivers, the getstat entry for an SCF driver should either use the stack passed to it, or allocate a special getstat stack on entry and free it before returning to SCFMan.

```
            * On entry we have:
            * a2 points to the device static storage
            * a6 points to the system global area
            *
            _Entry:
0000 000e               dc.w     _InitDisk
0002 003a               dc.w     _ReadDisk
0004 0066               dc.w     _WritDisk
0006 0098               dc.w     _GetStat
0008 00c4               dc.w     _PutStat
000a 00f2               dc.w     _Term
000c 0000               dc.w     0

            *
            * On entry we have:
            * a1 points to the device descriptor
            * a2 points to the device static storage
            * a6 points to the system global area
            *
            _InitDisk
                        NEWSTACK
            *
001c 48e7               movem.l a4/a6,-(sp)
0020 2009               move.l   a1,d0
0022 220a               move.l   a2,d1
0024 2f0e               move.l   a6,-(sp)
0026=6100               bsr      Init               (dd, statics, sysglobs)
002a 588f               addq.l   #4,sp              throw away arg space
002c 4cdf               movem.l (sp)+,a4/a6
0030 3200               move.w  d0,d1
            *
            * restore the old stack
                        OLDSTACK
0034 6600               bne      _Error
0038 4e75               rts

            *
            * On entry we have:
            *
            * (d0.l) number of contiguous sectors to read
            * (d2.l) logical sector number
            * (a1) path descriptor
            * (a2) static storage
            * (a4) process descriptor
            * (a5) caller's registers
            * (a6) system globals
            *
            _ReadDisk
                        NEWSTACK
```

```
               *
0048 48e7            movem.l a4/a6,-(sp)
004c 2202            move.l  d2,d1
004e 48e7            movem.l a1/a2/a6,-(sp)    prepare parameters

0052=6100            bsr     ReadDisk          (ct, lsn, pathd, statics, sysglobs)
0056 4fef            lea.l   (3*4)(sp),sp      throw away arg space
005a 4cdf            movem.l (sp)+,a4/a6
005e 3200            move.w  d0,d1
               *
               * restore the old stack
               *
                     OLDSTACK
0062 662e            bne.s   _Error
0064 4e75            rts
               *
               * On entry we have:
               *
               * (d0.l) number of contiguous sectors to write
               * (d2.l) logical sector number
               * (a1) path descriptor
               * (a2) static storage
               * (a4) process descriptor
               * (a5) caller's registers
               * (a6) system globals
               *
               _WritDisk
                     NEWSTACK
               *
0074 48e7            movem.l a4/a6,-(sp)
0078 2202            move.l  d2,d1
007a 48e7            movem.l a1/a2/a6,-(sp)

007e=6100            bsr     WritDisk          (ct, lsn, pathd, statics, sysglobs)
0082 4fef            lea.l   12(sp),sp         throw away arg space
0086 4cdf            movem.l (sp)+,a4/a6
008a 3200            move.w  d0,d1
               *
               * restore the old stack
               *
                     OLDSTACK
008e 6602            bne.s   _Error
0090 4e75            rts



0092 003c _Error     ori     #Carry,ccr
0096 4e75            rts
```

```
            *
            * On entry we have:
            *
            * (d0.w) Code
            * (a1) path descriptor
            * (a2) static storage
            * (a4) process descriptor
            * (a5) caller's registers
            * (a6) system globals
            *
            _GetStat
                        NEWSTACK
            *
00a6 48e7               movem.l a4/a6,-(sp)
00aa 2209               move.l  a1,d1
00ac 48e7               movem.l a2/a4/a5/a6,-(sp)

00b0=6100               bsr     GetStat         (code, pathd, statics, procd, regs, sysglobs)
00b4 4fef               lea.l   16(sp),sp       throw away arg space
00b8 4cdf               movem.l (sp)+,a4/a6
00bc 3200               move.w  d0,d1
            *
            * restore the old stack
            *
                        OLDSTACK
00c0 66d0               bne.s   _Error
00c2 4e75               rts

            *
            * On entry we have:
            *
            * (d0.w) Code
            * (a1) path descriptor
            * (a2) static storage
            * (a4) process descriptor
            * (a5) caller's registers
            * (a6) system globals
            *
            _PutStat
                        NEWSTACK
            *
00d2 48e7               movem.l a4/a6,-(sp)
00d6 2209               move.l  a1,d1
00d8 48e7               movem.l a2/a4/a5/a6,-(sp)

00dc=6100               bsr     PutStat         (code, pathd, statics, procd, regs, sysglobs)
00e0 4fef               lea.l   16(sp),sp       throw away arg space
00e4 4cdf               movem.l (sp)+,a4/a6
00e8 3200               move.w  d0,d1
```

```
          *
          * restore the old stack
          *
                    OLDSTACK
00ec 6600           bne       _Error
00f0 4e75           rts

          *
          * On entry we have:
          *
          * (a1) device descriptor
          * (a2) static storage
          * (a6) system globals
          *
          _Term
                    NEWSTACK
          *
0100 48e7           movem.l a4/a6,-(sp)
0104 2009           move.l    a1,d0
0106 220a           move.l    a2,d1

0108=6100           bsr       Term                (dd, statics, sysglobs)
010c 4cdf           movem.l (sp)+,a4/a6
0110 3200           move.w  d0,d1
          *
          * restore the old stack
          *
                    OLDSTACK
0114 6600           bne       _Error
0118 4e75           rts


          _srqmem:
011a 2f0a           move.l    a2,-(sp)
011c=4e40           os9       F$SRqMem
0120 6404           bcc.b     srqmemx1
0122 70ff           moveq.l #-1,d0
0124 6002           bra.b     srqmemx
          srqmemx1
0126 200a           move.l    a2,d0
          srqmemx
0128 245f           move.l    (sp)+,a2
012a 4e75           rts

          *
          *         DoSRtMem(ptr, size)
          *
          DoSRtMem:
012c 2f0a           move.l    a2,-(sp)
```

```
012e 2440           move.l   d0,a2
0130 2001           move.l   d1,d0
0132=4e40           os9      F$SRtMem
0136 6404           bcc.b    DoSrtMx
0138=4e40           os9      F$SysDbg
          DoSrtMx
013c 245f           move.l   (sp)+,a2
013e 4e75           rts

          SysDebug:
0140=4e40           os9      F$SysDbg
0144 4e75           rts

          * MoveDate(dest, src, length)
          MoveData:
0146 48e7           movem.l d2/a0/a2,–(sp)
014a 2440           move.l   d0,a2            destination
014c 2041           move.l   d1,a0            source
014e 242f           move.l   4*4(sp),d2       length
0152 7200           moveq.l #0,d1             sweep for error code
0154=4e40           os9      F$Move
0158 2001           move.l   d1,d0            move error code to d0
015a 4cdf           movem.l (sp)+,d2/a0/a2
015e 4e75           rts

          * QueryWDOwn(SysGlobs) returns uchar D_SCOwn
00000041  D_SCOwnequ         D_IOGlob+$41     Field in IO_Globals defined by GMX
          QueryWDOwn:
0160 2f0e           move.l   a6,–(a7)         being very suspicious
0162 2c40           move.l   d0,a6
0164 7000           moveq.l #0,d0
0166=102e           move.b   D_SCOwn(a6),d0
016a 2c5f           move.l   (a7)+,a6
016c 4e75           rts

          * SetWDOwn(new, SysGlobs) returns new
          SetWDOwn:
016e 2f0e           move.l   a6,–(a7)         being very suspicious
0170 2c41           move.l   d1,a6
0172=1d40           move.b   d0,D_SCOwn(a6)
0176 2c5f           move.l   (a7)+,a6
0178 4e75           rts


017a 3031 HexTbl:   dc.b     ’0’,’1’,’2’,’3’,’4’,’5’,’6’,’7’,’8’,’9’,’A’,’B’,’C’,’D’,’E’,’F’

          *
          * _Ev_link(name) returns an event ID number or -1
          *
```

```
018a 48e7  _Ev_link:   movem.l d1/a0,–(sp)
018e 2040              move.l  d0,a0
0190=323c              move.w  #Ev$Link,d1
0194=4e40              os9     F$Event
0198 6402              bcc.b   evlinkX
019a 70ff              moveq.l #-1,d0        Error return
019c 4cdf  evlinkX     movem.l (sp)+,d1/a0
01a0 4e75              rts

           *
           * _Ev_creat(name, *Errno) returns an event ID number or -1
           *
01a2 48e7  _Ev_Creat:  movem.l d1-d3/a0/a1,–(sp)
01a6 2040              move.l  d0,a0         Event name
01a8 2241              move.l  d1,a1         Error number pointer
01aa 7000              moveq.l #0,d0         Initial event variable value (semaphore open)
01ac=323c              move.w  #Ev$Creat,d1
01b0 7401              moveq.l #1,d2         Autoinc for wait
01b2 76ff              moveq.l #-1,d3        Autoinc for signal
01b4=4e40              os9     F$Event
01b8 640a              bcc.b   evcreatX
01ba 70ff              moveq.l #-1,d0        Error return
01bc 32bc              move.w  #0,(a1)       sweep high-order word of Errno
01c0 3341              move.w  d1,2(a1)      place error code
01c4 4cdf  evcreatX    movem.l (sp)+,d1-d3/a0/a1
01c8 4e75              rts

           *
           * _Ev_Unlink(EvID)
           *
01ca 2f01  _Ev_Unlink: move.l d1,–(sp)
01cc=323c              move.w  #Ev$UnLnk,d1
01d0=4e40              os9     F$Event
           * ignore errors
01d4 221f              move.l  (sp)+,d1
01d6 4e75              rts

           *
           * _Ev_Del(Name)
           *
01d8 48e7  _Ev_Del:    movem.l d1/a0,–(sp)
01dc 2040              move.l  d0,a0
01de=323c              move.w  #Ev$Delet,d1
01e2=4e40              os9     F$Event
01e6 4cdf              movem.l (sp)+,d1/a0   ignore errors
01ea 4e75              rts

           *
           * _Ev_Wait(EvID)
```

```
               *
01ec 48e7  _Ev_Wait: movem.l d1-d3,-(sp)
01f0=323c            move.w  #Ev$Wait,d1
01f4 7400            moveq.l #0,d2
01f6 7600            moveq.l #0,d3
01f8=4e40            os9     F$Event
01fc 4cdf            movem.l (sp)+,d1-d3
0200 4e75            rts
           *
           * _Ev_Signal(EvID)
           *
0202 2f01  _Ev_Signal: move.l d1,-(sp)
0204=323c            move.w  #Ev$Signl,d1
0208=4e40            os9     F$Event
020c 221f            move.l  (sp)+,d1
020e 4e75            rts


           dosleep:
0210=4e40            os9     F$Sleep
0214 6402            bcc.b   dosleepX
0216 70ff            moveq.l #-1,d0 only one error's possible: NoClk
0218 4e75  dosleepX  rts

           *
           * Awake(process)
           *
021a 2f01  AWake:    move.l  d1,-(sp)
021c=323c            move.w  #S$Wake,d1
0220=4e40            os9     F$Send
0224 221f            move.l  (sp)+,d1
0226 4e75            rts


           * SetIRQ(vector, priority, IRQRtn, DevStatics, port)
0228 48e7  SetIRQ:   movem.l a0/a2/a3,-(sp)
022c 206f            move.l  (4*4)(sp),a0     IRQ service routine pointer
0230 246f            move.l  (4*5)(sp),a2     Device static storage
0234 266f            move.l  (4*6)(sp),a3     Port address
0238=4e40            os9     F$IRQ
023c 6508            bcs.b   SetIRQE
023e 7000            moveq.l #0,d0            Signal no error
0240 4cdf  SetIRQX   movem.l (sp)+,a0/a2/a3
0244 4e75            rts

0246 7000 SetIRQE    moveq.l #0,d0            sweep d0
0248 3001            move.w  d1,d0            Put error where it's expected
024a 60f4            bra.b   SetIRQX
```

```
              *
              * IRQRtn
              * Called by the kernel
              * a2 points to static storage
              * a3 is the port address
              * a6 points to system globals
              *
              * d2-d7/a4-a5/a7 must be preserved
024c 200a     IRQRtn:  move.l  a2,d0         Dev statics
024e 220b              move.l  a3,d1         port address
              * skip sysglobs. The C routine doesn't use them.
0250=6100              bsr     C_IRQRtn
0254 4a40              tst.w   d0            Is d0 0? (and clear carry)
0256 6704              beq.b   IRQX
0258 003c              ori.b   #Carry,ccr
025c 4e75     IRQX     rts

              *
              * _chkMem(size, permissions, ptr, proc_desc)
              *
              _chkMem:
025e 48e7              movem.l a2/a4,-(sp)
0262 246f              move.l  3*4(sp),a2    ptr
0266 286f              move.l  4*4(sp),a4    proc_desc
              * d0 and d1 are already loaded
026a=4e40              os9     F$ChkMem
026e 6508              bcs.b   ChkMemEr
0270 7000              moveq   #0,d0         return 0 if OK
              ChkMemX
0272 4cdf              movem.l (sp)+,a2/a4
0276 4e75              rts
              ChkMemEr
0278 3001              move.w  d1,d0         return the error code from ChkMem
027a 48c0              ext.l   d0
027c 60f4              bra.b   ChkMemX

0000027e               ends
```

30.8 Header Files

30.8.1 drvr.h

```
#define RBF_MAXDRIVES   3
#define MAXLUN          0    /*Only handle one logical unit per controller    */
#define MAXSCSI         7    /*Support all SCSI ids                           */
#define RETRY_MAX       2    /*Number of retries on I/O errors                */
#ifndef TRUE
```

```
#define TRUE                1
#define FALSE               0
#endif

typedef unsigned char uchar;
typedef unsigned long ulong;
typedef char boolean;

typedef struct mstatics {
     sysioStatic v_sysio;              /*kernel static storage                    */
     uchar v_ndrv;                     /*number of drives                         */
    uchar v_dumm1[7];                  /*reserved                                 */
    struct rbfdrive drv[RBF_MAXDRIVE];        /* drive table                      */
    /*
        Driver static storage
    */
    uchar V_CDB[10];                   /*CDB (SCSI Command block )                */
    ulong v_Sectors;
    ulong v_Bytes;
    ulong EvID;
}*MyStatics;

/*
    GMX SCSI I/O Board constants
*/

typedef struct GMXBd {
    volatile uchar chip1, chip2;
    volatile char chip3;
    uchar reserved[4];
    union {
        volatile ushort W_DataBuf;
        volatile ulong L_DataBuf;
    }Databuffer;
    volatile ushort BD_Address;
}*Board;
#define WD_SELECT               chip1
#define WD_AUX                  chip1
#define WD_READ_REG             chip2
#define WD_WRITE_REG            chip2


#define BD_STATUS               chip3
#define BD_CONTROL              chip3
```

```
#define BD_PUBLIC_BUF            0x08000
#define BD_ENABLE_INT            0x080
#define BD_RESET                 0x040
/*
    WD 33C93A constants
*/

#define WD_OWNID_FS2      0       /*Clock divider for 8—10 mhz clock              */
#define WD_TIMEOUT        32      /*Timeout value for chip                        */
#define WD_OWNID_EAF      0x08    /*Enable advanced features                      */
#define WD_STR_INIT_VALUE 0x020   /* No sync transfers,
                                   but use shortest transfer period              */
#define WD_CTL_DMWD       0x040   /*DMA will use a WD bus                         */
#define WD_CTL_EDI        0x08    /*Generate endiing disconnect interrupt         */
#define WD_CTL_HSP        0x01    /*Hold on parity error                          */
#define WD_SAT_OK         0x16    /*SAT command completed successfully            */

#define WD_OWNID          0       /*Owner ID and general initialization register  */
#define WD_CONTROL        1
#define WD_TOTSECTS       3
#define WD_CDB1           3
#define WD_TARGET_STAT    15
#define WD_TARGET_LUN     15
#define WD_CMD_PHASE      16
#define WD_SYNCTRANS      17      /*Synchronous transfer register                 */
#define WD_XFRCT1         18
#define WD_DESTID         21      /*Destination ID register                       */
#define WD_SCSI_STAT      23      /*SCSI status register                          */
#define WD_CMDREG         24      /*33C93A commands go here                       */

/*33C93A Commands */
#define WD_RESET          0x0
#define SCSI_X_SAT        9       /*33C93A Select and transfer                    */

#define WD_DPD_In         0x040   /*Data phase direction                          */
#define WD_DPD_Out        0x00    /*The other data phase direction                */

/*
    SCSI Commands
 */
#define SCSI_TEST_UNIT_READY 0
#define SCSI_REZERO_UNIT 1
#define SCSI_REQUEST_SENSE 3
#define SCSI_FORMAT_UNIT4
#define SCSI_READOP       8
```

```
#define SCSI_WRITEOP        10
#define SCSI_TARGET_STAT  15
#define SCSI_MODE_SELECT 21
#define SCSI_MODE_SENSE   26
#define SCSI_START_UNIT    27
#define SCSI_READ_CAPACITY 37
#define SCSI_VERIFY           47

#define SENSE_CMD_LEN      6
#define READ_CMD_LEN       6
#define REZERO_CMD_LEN  6
#define FORMAT_CMD_LEN 6
#define WRITE_CMD_LEN     6
#define READY_CMD_LEN     6
#define VERIFY_CMD_LEN    10
#define READCAP_CMD_LEN10


#define SETUP_CMD(CDB,op,lsn,len) CDB[0] = op, CDB[1] = (lsn >> 16),\
                                  CDB[2] = (lsn >> 8), CDB[3] = lsn,\
                                  CDB[4] = len, CDB[5] = 0

#define SETUP_CMD_10(CDB,op,b2,lsn,len) CDB[0] = op, CDB[1] = b2,\
                                  CDB[2] = (lsn >> 24),\
                                  CDB[3] = (lsn >> 16),\
                                  CDB[4] = (lsn >> 8),\
                                  CDB[5] = lsn, CDB[6] = 0,\
                                  CDB[6] = (len >> 8), CDB[8] = len,\
                                  CDB[9] = 0
#define ClaimController(EvID)  _Ev_Wait(EvID)                          /* pg. 475 */
#define ReleaseController(EvID) _Ev_Signal(EvID)                       /* pg. 475 */

/*
   Function declarations
*/
LL_Get();
Do_WD_Reset();
void LL_Put();
void Set_XFrCt();
int Get_XFrCt();
void Set_Control();
```

30.8.2 Prototypes.h

```
int SAT_Error(int, Board, MyStatics);
int DeviceCheck(MyStatics, u_char);
int Init(mod_dev *, MyStatics, void *);
int Init33C93A(Board, boolean);
int Cond_InitDrive(MyStatics, struct rbf_opt *, Rbfdrive, void *);
int InitDrive(Board, boolean, boolean, u_int16 *,
        u_char, MyStatics, void **, u_char *, u_int32 *, void *);
int Make_UnitReady(u_int32, u_char, MyStatics);
int GetCapacity(u_int32, boolean, u_int16 *, u_int32 *, u_char, MyStatics);
int SetSectorSize(MyStatics, u_char, u_int16);
int direct_command(REGISTERS *, procid *, struct rbf_opt *, MyStatics);
int Exec(int, u_char, u_int32 *, u_char, MyStatics);
int C_IRQRtn(MyStatics, Board);
u_int32 MakeEvent(u_int32, int *);
void DeleteEvent(u_int32, u_int32);
u_int32 addoffsets(u_int32, u_int32, boolean, u_char, u_int16, u_int16, u_char);
int BoundsCheck(u_int32, int, int, boolean);
int ReadDisk(int, u_int32, Pathdesc, MyStatics, void *);
int BaseRead(int, u_int32, u_char *, struct rbf_opt *, MyStatics);
int ReadSector0(u_int32, MyStatics, u_char *, Rbfdrive, struct rbf_opt *);
void LL_Put(Board, u_char, u_char);
int Do_WD_Reset(Board);
int LL_Get(Board, u_char);
void Set_Control(Board, u_char);
void Set_XFrCt(Board, u_int32);
int Get_XFrCt(Board);
void BdReset(Board, void *);
int GetStat(int, Pathdesc, MyStatics, procid *, REGISTERS *, void *);
int PutStat(int, Pathdesc, MyStatics, procid *, REGISTERS *, void *);
int Term(mod_dev *, MyStatics);
int WritDisk(int, u_int32, Pathdesc, MyStatics, void *);
int BasicWrite(int, u_int32, u_char *, struct rbf_opt *, MyStatics);
```

30.8.3 lowlevel.h

```
#define GET_SCSI_STATUS(port)      LL_Get(port, WD_SCSI_STAT)          /* pg. 458 */
#define GET_SCSI_TARGETSTAT(port) LL_Get(port, SCSI_TARGET_STAT)/* pg. 458 */
#define SET_OWNID(port,value)      LL_Put(port, value, WD_OWNID)       /* pg. 458 */
#define SET_SYNCTRANS(port,val)    LL_Put(port, val, WD_SYNCTRANS)     /* pg. 458 */
#define SET_TARGET(port,value)     LL_Put(port, value, WD_DESTID)      /* pg. 458 */
#define SET_CMD(port,value)        LL_Put(port, value, WD_CMDREG)      /* pg. 458 */
#define SET_CMDPHASE(port,value) LL_Put(port, value, WD_CMD_PHASE)/* pg. 458 */
```

```
#define BD_EnableInt(port)          port->BD_CONTROL = BD_ENABLE_INT
```

30.8.4 dcmd.h

```
/*
    This is the structure that is passed to the getstat and putstat
    routines.
*/
typedef struct d_cmd {
    int dcmdsync,                   /*sink code—must be DCMDSYNC                       */
            manager,                /*file manager code, pd_dtype from _gs_opts()      */
            device;                 /*device type code                                 */
    void *dcmdblk;                  /*device driver specific command                   */
}*Dcmd;

/*
    General definitions
*/

#define DCMDSYNC 0xCA7CA11          /*this code validates the command block            */

/*  device type codes:
    These are specific to the devices. The drivers can use this field
    to validate that the call that arrived is for the device that they
    control.
*/
#define SCSIdevice 0x5C51           /*SCSI bus device                                  */

/*
    definitions for SCSI direct command structure.
*/


/*
    scsi command block definitions.
    this block is the SCSI command specification block used to
    communicate between the calling program and the driver.
*/
typedef struct cmdblk {
    uchar *_cb_cmdptr;              /*pointer to the scsi command                      */
    void *_cb_datptr;               /*pointer to the data area                         */
    void *_cb_errptr;               /*pointer to the error data area                   */
    ulong _cb_cmdlen;               /*length of the command block                      */
    ulong _cb_datlen;               /*expected data length                             */
    ulong _cb_errlen;               /*expected error length                            */
    ulong _cb_scsi_id;              /*the target id (filled in by driver)              */
    uchar _cb_pd_lun;              /*the target lun ( also filled in by driver )     */
    uchar _cb_xfer;                /*data input/output flag                          */
#define INPUT           0
#define OUTPUT          1
}*Cmdblk;
```

30.9 Makefile

```
CSRC =      Errors.c Init.c InitDrive.c term.c\
            exec.c irq.c misc.c read.c read0.c\
            scsi.c setmode.c static. write.c direct.c

ASRC =      drmain.a

GLUE =      drmain.r

FILES =     Errors.r Init.r term.r\
            InitDrive.r exec.r irq.r misc.r\
            read.r read0.r setmode.r stat.r direct.r write.r scsi.r

CFLAGS =    -r -tp020c
RFLAGS =    -m4 -q
LFLAGS =    -g
SLIB =      /h0/lib/sys.l
MLIB =      /h0/lib/math.l


tstdrvr:    $(FILES) $(GLUE)
            l68 $(LFLAGS) $(GLUE) $(FILES) -l=$(SLIB) -l=$(MLIB) -o=tstdrvr -msw >-map.tst
            patchmod tstdrvr 4096
            fixmod -x -uo0.0 tstdrvr

Errors.r: Errors.c

Init.r : Init.c

term.r : term.c

InitDrive.r: InitDrive.c

exec.r: exec.c

irq.r: irq.c
```

```
misc.r: misc.c

read.r: read.c

read0.r: read0.c

setmode.r: setmode.c

stat.r: stat.c

direct.r: direct.c

write.r: write.c

scsi.r: scsi.c
```

If the driver is not made by the super user, the super user must run a script to "claim" the driver module:

```
chown –o=0.0 /h0/cmds/peter/tstdrvr
fixmod –uo=0.0 /h0/cmds/peter/tstdrvr
attr /h0/cmds/peter/tstdrvr –prpwperwe
```

30.10 Patchmod

The driver module must request enough static storage for the device static storage plus enough stack space. Since C doesn't know that there is any static storage, the amount of device static storage must be set by hand. The actual device static storage structure is fairly small—around 300 bytes, but the makefile requests four kilobytes of device static storage to leave plenty of space for the driver's stack. The value passed to ***Patchmod*** by the makefile must be the same as the `Stk` equate in drmain.a.

Patchmod is a simple program that updates the memory requirement field in a file containing a module.

```
#include <stdio.h>
#include <module.h>
#include <errno.h>
#include <const.h>

main(int argc, char **argv)
```

```
{
    int size;
    u_int32 ct;
    char *Name;
    path_id pathnum;


    if(argc != 3){
        Usage();
        exit(1);
    }
    if(strcmp(argv[1], "-?") == 0){
        Usage();
        exit(0);
    }
    Name = argv[1];
    if((errno = _os_open(Name, 7, &pathnum)) != SUCCESS){
        perror("cannot open file");
        exit(errno);
    }

    if((size = atoi(argv[2])) == 0){
        Usage();
        exit(1);
    }
    _os_seek(pathnum, 0x38); /*Seek to memory-amount location */
    ct = sizeof size;
    if((errno = _os_write(pathnum, &size, &ct)) != SUCCESS){
        fprintf(stderr, "Cannot update memory amount in %s\n", Name);
        exit(errno);
    }
    (void)_os_close(pathnum);
    exit(0);
}



Usage()
{
    printf("Patchmod <file> <mem>\n");
    printf("\tUpdate the memory requirement of <file> to <mem>\n");
}
```

30.11 QuantumCache

Microware uses a version of the following program to demonstrate the SCSI direct command interface. The official version operates on CDC Wren disk drives. This version is slightly modified to work with Quantum Prodrive disk drives.

```
/*
    Quantumcache—enable the cache on Quantum prodrive
*/

/*
    Copyright 1990 by Microware Systems Corporation Reproduced Un-
    der License. This source code is the proprietary confidential property of
    Microware Systems Corporation, and is provided to licensee solely for
    documentation and educational purposes. Reproduction, publication,
    or distribution in any form to any party other than the licensee is strictly
    prohibited.
*/


/*
    This utility, besides being useful in manipulating the cache on
    Quantum drives, provides an example of the direct command feature
    of the Microware drivers.

    Edition History:
     Ed   Date       Reason                          Who
    ----------------------------------------------------
     1    90/04/09   Created (for Wren)              Rwb
     2    90/06/01   Modified for Swift 126          Rwb
     3    91/12/28   Converted from Wren to Quantum  pcd
     4    93/06/10   Converted to ANSI               pcd
*/

_asm("_sysedit: equ 3");

#include <stdio.h>
#include <sgstat.h>
#include <sg_codes.h>
#include <modes.h>
#include <errno.h>
#include <const.h>
typedef unsigned char uchar;
typedef unsigned long ulong;
#include "../dcmd.h"
```

```
#define TRUE                    1
#define FALSE                   0
#define CACHEON                 TRUE
#define CACHEOFF                !CACHEON

#define NOCACHEPAGE             FALSE
#define SHOWCACHEPAGE           TRUE
#define CDB_STD                 6
#define SC_INQUIRY              0x12
#define SC_MODESENSE            0x1a
#define SC_MODESELECT           0x15

static char devs[14][16];               /*device names from command line         */

static char *nulstr = "";               /*a nice way to print nothing at all     */
static char *equstr = "===================================";
static char *cpagestr = "====== Cache page information =====";

static struct d_cmd dcd;                /*direct command structure               */
static struct cmdblk cmd;               /*command block for the driver           */
static struct sgbuf opt;                /*place for the options info from drive  */

static union scsipkt {
    struct std_str {
        uchar sp_opcode;                /*the opcode                             */
        unsigned sp_lun : 3;            /*logical unit (filled in by driver)     */
        unsigned sp_lbamsbs : 5;        /*the block address (msbs)               */
        char sp_lba[2];                 /*(the rest of) the block address        */
        char sp_blkcnt;                 /*the block count                        */
        uchar sp_options;               /*command options                        */
    }std;
    struct ext_str {
        uchar sp_opcode;                /*the opcode                             */
        unsigned sp_lun : 3;            /*logical unit (filled in by driver)     */
        unsigned sp_zero : 5;           /*zero                                   */
        ulong sp_lba;                   /*logical block address                  */
        uchar sp_zero2;                 /*zero                                   */
        uchar sp_count[2];              /*transfer count                         */
        uchar sp_options;               /*command options                        */
    }ext;
}spkt; /*This structure is the SCSI command block */


/*
    this is the structure that defines request sense information
    from the Quantum drives.
```

```
*/

static union errdetails {
    struct rbferr {
        unsigned ed_valid : 1,          /*error is valid                          */
                 ed_class : 3,          /*error class = 7                         */
                 ed_zero : 4;           /*always 0                                */
        uchar ed_seg;                   /*segment number always 0                 */
        unsigned ed_filemrk : 1,        /*filemark                                */
                 ed_eom : 1,            /*end of medium                           */
                 ed_ili : 1,            /*incorrect length indicator              */
                 ed_zero2 : 1,          /*always zero                             */
                 ed_main : 4;           /*main sense key                          */
        uchar ed_info[4],               /*info byte [lba]                         */
                 ed_senslen;            /*additional sense info length            */
        ulong ed_zero3;                 /*always zero                             */
        uchar ed_code,                  /*error code                              */
                 ed_zero4,              /*always 0                                */
                 ed_fru;                /*fru code                                */
        unsigned ed_fpv : 1,            /*field pointer valid                     */
                 ed_cd : 1,             /*command/data bit                        */
                 ed_zero5 : 2,          /*always zero                             */
                 ed_bpv : 1,            /*block pointer valid                     */
                 ed_bitptr : 3;         /*bit pointer                             */
        uchar ed_fptr[2];               /*field pointer                           */
    }rerr;
    struct sbferr {
        unsigned ed_valid : 1,          /*error is valid                          */
                 ed_class : 3,          /*error class = 7                         */
                 ed_zero : 4;           /*always 0                                */
        uchar ed_seg;                   /*segment number always 0                 */
        unsigned ed_filemrk : 1,        /*filemark                                */
                 ed_eom : 1,            /*end of medium                           */
                 ed_ili : 1,            /*incorrect length indicator              */
                 ed_zero2 : 1,          /*always zero                             */
                 ed_main : 4;           /*main sense key                          */
        uchar ed_info[4];               /*info byte [lba]                         */
        uchar ed_senslen;               /*additional sense info length            */
        uchar ed_cpsrc;                 /*COPY source sense data ptr              */
        uchar ed_cpdest;                /*COPY destination sense data ptr         */
        uchar ed_zero3[2];              /*always zero                             */
        uchar ed_recov[2];              /*# recoverable errors                    */
        uchar ed_cptstat;               /*COPY target status                      */
        uchar ed_cptsens[8];            /*COPY target sense data (0cminus7)       */
    }serr;
}edat;


/*
    inquiry data structure
*/
struct inquirdat {
    uchar iq_type;                  /*device type                  */
    unsigned iq_rmb : 1,            /*always 0                     */
             iq_typqual : 7,        /*device type qualifier        */
             iq_iso : 2,            /*ISO version                  */
             iq_ecma : 4,           /*ECMA version                 */
             iq_ansi : 2,           /*ANSI version                 */
             iq_zero : 4,           /*always 0                     */
             iq_datfmt : 4;         /*response data format         */
    char iq_addlen,                 /*additional length            */
             iq_quantres1,          /*Quantum uniq = 0             */
             iq_quantres2[2],       /*Quantum reserved = 0         */
             iq_vendid[8],          /*vendor id QUANTUM            */
             iq_prodid[16],         /*product id                   */
             iq_revlev[4];          /*revision level               */
}idat;


/*definitions used to access parameters in mode sense */
#define PCF_CURRENT         0x00 /*current parameters              */
#define PCF_CHANGE          0x01 /*changeable drive parameters     */
#define PCF_DEFAULT         0x02 /*default drive parameters        */

/*
    mode sense data structure (basic, must add pages to be complete )
*/
typedef struct modesen_str {
    /*parameter list header */
    uchar msn_datlen;               /*length of sense info         */
    uchar msn_medtype;              /*medium type                  */
    unsigned msn_wp : 1;            /*write protect 1=WP ON        */
    unsigned msn_res1 : 7;          /*unused                       */
    uchar msn_bdlen;                /*block descriptor length      */
    /*block descriptor */
    uchar msn_denscode;             /*density code                 */
    uchar msn_numblks[3];           /*number of blocks             */
    uchar msn_res2;                 /*reserved                     */
    uchar msn_blklen[3];            /*block length                 */
}modesense;
```

```
static struct page37 {
    modesense mds;
    /*page 37 – The Quantum vender-specific cache information */
    #define PAGE_37 0x37
    uchar msn_p37code,                  /*page code                          */
              msn_p37plen;              /*page length (0x0e)                 */
    unsigned msn_p37res:2,              /*reserved bits                      */
              msn_p37psm:1,             /*preserve synchronous mode          */
              msn_p37ssm:1,             /*send synchronous message           */
              msn_p37wie:1,             /*write index enable                 */
              msn_p37po:1,              /*prefetch only                      */
              msn_p37pe:1,              /*prefetch enable                    */
              msn_p37ce:1;              /*cache enable                       */
    uchar msn_p37ncache,                /*number of cache segments           */
              msn_p37mnpf,              /*minimum pre-fetch                  */
              msn_p37mxpf,              /*max pre-fetch                      */
              msn_p37resvb[10];         /*8 reserved bytes                   */
}cpag;


static char *devtypes[] = {
    "Direct Access (disk drive)",
    "Sequential Access (mag tape)",
    "Printer",
    "Processor",
    "Write once, Read Multiple (WORM)",
    "CD-ROM",
    "Scanner",
    "optical Memory Device (some optical disks)",
    "Changer Device (jukeboxes)",
    "Communications Device"
};


static char *ansiver[] = {
    "Not compliant to ANSI standards.",
    "ANSI X3.131–1986 (SCSI 1)",
    "ANSI X3.131 X3T9.2/86–109 (SCSI 2 working draft)"
};


static char *helpline[] = {
"Syntax: .../quantumcache {<opts>}<device> {<opts>
        "Function: view/enable/disable cache on Quantum Prodrive drives.\n",
        " no options specified will print current cache condition\n",
        "Options:\n",
        " -e enable cache\n",
        " -d disable cache\n",
        " -v printout information from inquiry command\n",
        "\n"
    };


/*
    Prototypes
*/
void printuse(FILE *);
void setcmdblk(char *, ulong, int, int);
int execute(int, uchar, uchar, uchar, uchar, int);
int identify(int);
int getcachepage(int);
int setcache(int, int);
void fieldcopy(char *, char *, int);
void prdevbits(void);
void show_inq(char *, int);
void show_sense(void);

/*
    printuse—print argument list
*/
void printuse(FILE * outfilepath)
{
    int i;

    for(i = 0; i < sizeof(helpline)/sizeof(helpline[0]); i++)
    fprintf(outfilepath, helpline[i]);
}


/*
    setcmdblk – set parameters in the command block
*/
void setcmdblk(char *datptr, /*buffer for I/O */
ulong datsize, /*number of bytes to transfer */
int scsize, /*SCSI command block size */
int direction) /*either INPUT or OUTPUT */
{
    /*set up the direct command structure */
    dcd.manager = opt.sg_class;         /*device manager                     */
    dcd.dcmdsync = DCMDSYNC;            /*set sync to validate the call      */
    dcd.device = SCSIdevice;            /*this is indeed a SCSI specific op              */
    dcd.dcmdblk = &cmd;                 /*pointer to command block                       */

    /*and now the SCSI driver required block */
    cmd._cb_cmdptr = (u_char *)&spkt;   /*pointer to the command                         */
    cmd._cb_datptr = datptr;            /*place for the data                             */
    cmd._cb_cmdlen = CDB_STD;           /*6 byte command block                           */
    cmd._cb_datlen = datsize;           /*the number of data bytes to xfer               */
    cmd._cb_xfer = direction;           /*read data flag                                 */
    cmd._cb_errptr = &edat;             /*pointer to the error block                     */
    cmd._cb_errlen = sizeof edat;       /*and the size reserved for it                   */
}


/*
    execute – prepare the command block for the driver and do the status
    call.
*/
int execute(int pn,                     /*path number                                    */
        uchar command,                  /*scsi command to perform                        */
        uchar lbam,                     /*logical unit                                   */
        uchar lba0,
        uchar lba1,
        int size)                       /*number of bytes to transfer                    */
{
    spkt.std.sp_opcode = command;
    spkt.std.sp_lbamsbs = lbam;
    spkt.std.sp_lba[0] = lba0;
    spkt.std.sp_lba[1] = lba1;
    spkt.std.sp_blkcnt = size;

    if( cmd._cb_xfer == INPUT )
        return _gs_dcmd( pn, &dcd);
    else
        return _ss_dcmd( pn, &dcd);
}


/*
    identify – prepare an inquiry command and send it.
*/
int identify(int pn)
{
    /*set up the command block for the driver */
    setcmdblk((char *)&idat, sizeof idat, CDB_STD, INPUT);
    /*now set up the SCSI command packet for inquiry command */
    return execute( pn, SC_INQUIRY, 0, 0, 0, sizeof idat );
}


/*
    getcachepage – read the cache page from the device
*/
int getcachepage(int pn)
{
    /*set up the command block for the driver */
    setcmdblk((char *)&cpag, sizeof cpag, CDB_STD, INPUT );

    /*now set up the SCSI command packet for inquiry command */
    return execute( pn, SC_MODESENSE, 0, (PCF_CURRENT << 5) | (PAGE_37),
            0, sizeof cpag );
}


/*
    setcache—enable/disable the cache for the device.
*/
int setcache(int pn, int condition)
{
    cpag.mds.msn_datlen = 0;            /*This field is reserved for modeset         */
    cpag.msn_p37code = PAGE_37;         /*insure that ps not set                     */

    /* set the cache enable bit in the page information */
    if(condition){
        cpag.msn_p37ce = condition;     /*Set cache enable                           */
        cpag.msn_p37pe = condition;
        cpag.msn_p37mnpf = 0;           /*Minimum prefetch                           */
        cpag.msn_p37mxpf = 16;          /*Maximum prefetch                           */
        cpag.msn_p37ncache = 8;         /*Number of cache entries                    */
    }else
        cpag.msn_p37ce = condition;     /*Set cache enable                           */


    /*set up the command block for the driver */
    setcmdblk((char *)&cpag, sizeof cpag, CDB_STD, OUTPUT );

    /*now set up the SCSI command packet for inquiry command */
    return execute( pn, SC_MODESELECT, 0, 0, 0, sizeof cpag );
}
```

```
/*
    fieldcopy – copy requested number of characters and null terminate
    dest.
*/
void fieldcopy(char *dest, char *src, int size)
{
    while( --size >=0 )
        *dest++ = *src++;

    *dest++ = 0;
}


/*
    prdevbits – print device information bits, only applies to SCSI 2 de-
    vices.
*/
void prdevbits( )
{
    register int shifter;

    shifter = (uchar)idat.iq_quantres2[1];  /*the info byte                  */

    puts(" Device Capabilities");
    shifter >>=4;
    if( shifter & 1 )
        puts("Synchronous operation supported.");
    shifter >>=1;

    switch( shifter & 0x3 ) {
        case 0:
                puts("8 bit wide transfers");
                break;
        case 1:
                puts("16 bit wide transfers");
                break;
        case 2:
                puts("32 bit wide transfers");
                break;
    }
}


/*
    This is a subroutine that will print out the inquiry information.
*/
```

```
void show_inq(char *devname,
int cpflag)                      /*cache page flag, if FALSE, don't print      */
{
    char devstr[64];


    printf("========= Device %s =============\n",devname);

    if( idat.iq_ansi > 2 )
        printf(" Responds with illegal Ansi compliance code.\n");
    else
        printf("Compliance: %s\n",ansiver[idat.iq_ansi]);

    switch ( idat.iq_datfmt ) {
        case 0:                  /*SCSI I                                      */
        case 1:                  /*sccs definition                             */
                if( idat.iq_type > 9 )
                    printf("Device type is UNDEFINED!\n");
        else
                    printf("Device Type: %s\n", devtypes[idat.iq_type]);
                break;

        case 2:                  /*SCSI II                                     */
                if( idat.iq_typqual > 9 )
                    printf("Device type is UNDEFINED!\n");
                else
                    printf("Device Type: %s\n", devtypes[idat.iq_typqual]);
                break;

        default:
                printf("Format of remaining data does not comply with any standard\n");
                break;
    }

    /*device function bits */
    if(idat.iq_datfmt == 2)
        prdevbits();             /*only works on SCSI II devices               */

    /*
        Inquiry vender specific fields (pre SCSI II) but are define for SCSI II
        as the same.
    */
    if(idat.iq_datfmt < 2) {
        printf(" ISO: %x ECMA: %x\n", idat.iq_iso, idat.iq_ecma);
        printf(" Media is %s.\n",idat.iq_rmb ? "removable" : "fixed");
        fieldcopy( devstr, &idat.iq_vendid[0], 8 );
        printf(" Vendor: %s\n", devstr );
        fieldcopy( devstr, &idat.iq_prodid[0], 16 );
        printf(" Product: %s\n", devstr );
        fieldcopy( devstr, &idat.iq_revlev[0], 4 );
        printf(" Revision: %s\n", devstr );
    }

    if( cpflag ) {                          /*only if it is a valid page          */
        puts( cpagestr );
        printf("Page code: 0x%x page length: 0x%x\n",
                cpag.msn_p37code & 0x3f,cpag.msn_p37plen);
        printf(" Cache is %s\n", cpag.msn_p37ce ? "ENABLED" : "Disabled");
        printf("Number of cache segments: 0x%x\n",cpag.msn_p37ncache );
        printf("Maximum Pre-fetch: 0x%x\n",cpag.msn_p37mxpf );
        printf("Minimum Pre-fetch: 0x%x\n",cpag.msn_p37mnpf );
        printf("Write index: %s\n",cpag.msn_p37wie == 0 ? "DISABLED" : "ENABLED");
        printf("Prefetch only: %s\n",cpag.msn_p37po == 0? "DISABLED" : "ENABLED");
        printf("Prefetch: %s\n",cpag.msn_p37pe == 0? "DISABLED" : "ENABLED");
    }
    puts(equstr);
}


/*
    show_sense – print results of a request sense if valid
*/
void show_sense()
{
    int mainstat,errorcode;
    uchar *infop;
    int i;

    if( edat.rerr.ed_valid != 0 ) {
        fputs(equstr,stderr);
        fprintf(stderr,"\n Sense Results\n");

        switch( opt.sg_class ) {
            case DT_RBF:
                    mainstat = edat.rerr.ed_main;
                    errorcode = edat.rerr.ed_code;
                    infop = &edat.rerr.ed_info[0];
                    break;
            case DT_SBF:
                    mainstat = edat.serr.ed_main;
                errorcode = 0;
                infop = &edat.serr.ed_info[0];
                break;
            default:
                fprintf(stderr,"Unknown device type\n");
                break;
        }
        fprintf(stderr," This is an %s Device\n",
            (opt.sg_class == DT_RBF) ? "RBF":"SBF");;

        fprintf(stderr," Main Status: 0x%x\n",mainstat);
        fprintf(stderr," Error Code: 0x%x\n",errorcode);
        fprintf(stderr," Info bytes (in HEX): ");
        for( i = 0; i < 4; i++ )
            fprintf(stderr," %x",*infop++);
        fprintf(stderr,"\n");
        fputs(equstr,stderr);
        fprintf(stderr,"\n");
    }else
        fprintf(stderr,"Error did not produce a valid sense result.\n");
}


/*
    Mainline
*/
main(int argc, char *argv[])
{
    char *p;
    path_id pn;
    int error;                          /*path number and error                    */
    u_int32 ct;
    int nooptions = TRUE;               /*no options requested (by default)        */
    int disable = FALSE,enable = FALSE; /*condition to set the cache               */
    int index = 0;                      /*start at 0 always                        */
    int verbose = FALSE;                /*don't print inquiry data                 */
    int nodevnames = TRUE;              /*no devices defined until user does it    */
    int errvalue;                       /*temporary holder on error occurrences    */
    char i;
    char devname[24];                   /*hope they don't have huge device names   */

    if( argc < 2 ) {
        printuse(stderr);
        fprintf(stderr,"Must provide at least one device name.\n");
        exit(0);
```

```
}

argv++;
while (−−argc >0) {
    if (*(p = *argv++) == '-') {
        p++;
        while (i = *p++) {
            switch (i | 0x60) {
                /* disable cache request */
                case 'd':
                                nooptions = FALSE;
                                disable = TRUE;
                                break;
                /*enable cache request */
                case 'e':
                                nooptions = FALSE;
                                enable = TRUE;
                                break;
                /*verbose mode—print cache and inquire info */
                case 'v':
                                verbose = TRUE;
                                break;
                /*get useage */
                case ('?' | 0x60):
                                printuse(stdout);
                                exit(0);
                                break;
                /*just fishing? */
                default:
                                printuse(stderr);
                                fprintf(stderr," unknown option %c\n\n", i);
                                exit(0);
                                break;
            }                           /*end switch                    */
        }                               /*end while chars left          */
    }else {
        /*must be a device name */
        if( index >13 ) {
            printuse(stderr);
            fprintf(stderr, "Too many devices!\n");
            exit(0);
        }
        if( *p == '/' ) {
            strcpy( &devs[index++][0], p ); /*copy string for use */
            nodevnames = FALSE;
        }else {
            printuse(stderr);
            printf(" Illegal argument: \"%s\"\n",p);
            exit(0);
        }
    }/*end if */
}/*end while args */

/*insure no conflict in arguments */
if( (enable == disable) && !(nooptions) ) {
    printuse(stderr);
    fprintf(stderr, "Confilicting options: -d -e\n");
    exit(0);
}

/*insure at least one device specified */
if(nodevnames) {
    printuse(stderr);
    fprintf(stderr, "Must provide at least one device name.\n");
    exit(0);
}

index = 0;
while( *(p = &devs[index][0]) != 0 ) {

    /*get a path to the device ( need to open @ form of device ) */
    strcpy( devname, p );
    strcat( devname, "@" );
    if((errno = _os_open(devname, S_IREAD, &pn)) != SUCCESS){
        perror(p);
        exit(errno);
    }

    do {
        /*read in the options for this device */
        ct = sizeof opt;
        if((error = _os_gs_popt(pn, &ct, &opt)) != SUCCESS) {
            perror("Error occurred durring read options.");
            break;
        }

        /*now try the identify command */
        if( (error = identify( pn )) ) {
            perror("Error occurred durring Identify command.");
            break;
        }

        /*if this is a Quantum drive, try to enable the cache */
        if( !(strncmp( "QUANTUM", &idat.iq_vendid[0], 3 )) ) {
            /*if it is a Quantum disk, we can at least try. */
            if( (error = getcachepage(pn)) ) {
                perror("Error attempting to read the cache page.");
                break;
            }

            if( nooptions ) {
                /*if not verbose, then print the current condition */
                if( !verbose )
                    fprintf( stdout, "%s: Cache %s\n", p,
                                    cpag.msn_p37ce ? "ENABLED" : "Disabled");
            }else {
                /*wants to enable or disable the cache */
                if( enable )
                    error = setcache(pn, CACHEON );
                else
                    error = setcache( pn, CACHEOFF );

                if( error ) {
                    fprintf(stderr, "Error during cache %s on %s.\n",
                                    enable ? "enable" : "disable", p);
                    break;
                }
            }

            /*if requested, print the inquiry info and cache pages */
            if( verbose )
                show_inq(p, SHOWCACHEPAGE);        /*print out the information */

        }else {
            show_inq(p, NOCACHEPAGE);
            fprintf( stderr, "%s is not a Quantum drive!\n",p);
        }

    }while(0);
    (void)_os_close(pn);              /*close path for this pass                */
    index++;                          /*next device                             */
}
errvalue = errno;
if( error )
    show_sense();
    exit(errvalue);

}



/*
    this is slated to become part of the standard library, but it
    hasn't happened yet.
*/
_asm("
** _gs_dcmd()
** _ss_dcmd()
**
** 'C' bindings for direct command to a device.
**
*
* Function: _gs_dcmd – get information from a device via direct command
* _ss_dcmd – send information to a device via direct command
*
* Syntax: int _gs_dcmd( pn, cmd )
* int pn; /*path number to the device as returned by open() */
* void *cmd; /*the direct command to be performed */
*
* int _ss_dcmd( pn, cmd )
* int pn; /*path number to the device as returned by open() */
* void *cmd; /*the direct command to be performed */
*
* Returns: 0 if all went well
* −1 on error, errno set to error number from driver
*
* Description:
* This is a mechanism where by a direct command can be issued to
* a device. The type of device of course determines the requirements of the
* command being sent. Refer to the documentation concerning the driver
* for the device to be communicated with.
*
* Caveats:
* Garbage in.... Garbage (possibly crash) out
*


_ss_dcmd:
    link a5,#0
    move.l a0,-(sp)
    move.l d1,a0 the command pointer
    move.l #SS_DCmd,d1 direct command code
    os9 I$SetStt
    bcs.s _gs_dcmderr
    clr.l d0 return all ok
    bra.s _gs_dcmdex

_gs_dcmd:
    link a5,#0
    move.l a0,-(sp)
    move.l d1,a0 the command pointer
    move.l #SS_DCmd,d1 direct command code
    os9 I$GetStt
    bcs.s _gs_dcmderr
    clr.l d0 return all ok
    bra.s _gs_dcmdex

* common code for both calls
_gs_dcmderr
    move.l #−1,d0 set error flag for return
    move.l d1,errno(a6) set errno to value from driver
_gs_dcmdex
    move.l (sp)+,a0
    unlk a5
    rts
");
```

Chapter 31

The Philosophy of OS-9

Small and *flexible* are OS-9's primary design goals. For many operating systems small and flexible work against each other, but since OS-9 interprets flexible as configurable, small and flexible fit together very well.

The most important parts of the OS-9 kernel consist of "glue" expressed as hooks and interfaces. The only I/O services in the OS-9 kernel are those services that must be in the kernel to insure that I/O systems can be installed and removed without interfering with one another. The collection of file managers from Microware, the file managers in this book, and the several commercially available file managers demonstrate that OS-9 accommodates a wide range of file managers smoothly. It does this precisely because there is very little code in the kernel that has anything to do with I/O.

Memory protection and cache control were added to the OS-9 kernel with only minor changes—calls to the MMU and cache control SVCs were added where appropriate—which were not dependent on the cache and MMU hardware. This update to the OS-9 kernel is a good example of the OS-9 design philosophy. The kernel remains small because it has almost no cache or MMU control code, and flexible because it supports a wide variety of configurations with hardware-specific SysCache and SSM modules.

The main avenue for user expansion of the OS-9 system is the I/O subsystem, but some services are not appropriate for the I/O subsystem. Occasionally the kernel is expanded to accommodate these services, but unless the service will be needed by a large part of the OS-9 community, special needs are met with system calls installed in a P2 module. This is a powerful tool. If a community needs a new kernel service, they can add it without changing OS-9; the kernel does not become bigger or slower. Those who don't need the new service are completely unaffected by it.

It is not an OS-9 rule that flexible must always be interpreted as configurable. The way the kernel handles various CPU and FPU chips is a case in point. One kernel will run any 68000-family CPU combined with no FPU, a 68881, or a 68882. The kernel includes code that recognizes the type of CPU and FPU and adjusts to the environment. This feature used several hundred bytes of code in the kernel, but the space cost of supporting all known 68xxx hardware in the kernel was seen as a good trade for the simplicity and slight speed advantage this approach had over building interfaces to CPU and FPU handler modules.

31.1 Weaknesses

Worst-Case Interrupt Latency Probably because of OS-9's imperative to be as configurable as possible, it defines almost no restrictions on interrupt service routines. Although Microware suggests vigorously that interrupt service routines should be short and simple, almost any behavior is permitted: an interrupt service routine can allocate and free memory; there are rumors that you can even fork a new process.

The result of this lack of regulation is that the kernel can be interrupted by an ISR that can execute an arbitrary set of SVCs. This requires a reentrant kernel (code and data), and since kernel data structures cannot practically be locked against interrupt code[1] the kernel is forced to mask interrupts for some operations on kernel data structures.

The maximum amount of time during which all interrupts can be masked in the kernel is too high. It can probably be reduced as the kernel is further tuned and improved, but it will be difficult to make worst case interrupt latency as good as it would have been if interrupt service routines were restricted to a small set of SVCs.[2]

File System Interface The kernel is quite unrestrictive about file managers and device drivers, but the utilities and drivers that support Microware file managers are tightly bound to those file managers. Consider the ugly hoops PCFM traverses to fit the expectations of RBF utilities and device drivers. It would be nice if the standard file manager interfaces went further than a set of system calls. An abstract file structure would let a single ***dir*** utility work with every file manager without alteration (including new and unusual file managers). So far we have no solution that is small, fast, compatible with existing standards, and configurable.

[1] Locks that shut out code in an interrupt service routine would require the ISR code to wait. If it is possible to make that work at all, the complexity it would cause would be frightening, to say nothing of what it would do to the execution time of the ISR.

[2] When interrupt latency is a serious concern, the worst case latency can be greatly decreased by avoiding operations that allocate or free memory: calls to the memory allocator, signals that queue, event creation or deletion, and I/O device attach and detach. These operations should be performed before and after real time activities.

31.2 Strengths

Passing over OS-9's practical strengths and moving directly to the philosophical advantages; the small and configurable philosophy works. It has done well at protecting the OS-9 kernel from ill-considered feature additions.[3] Features can be, and almost always are, added *outside* the OS-9 kernel. The kernel on my Micro-20 is 27562 bytes long. The OS-9 configuration for a minimal embedded system would use perhaps another kilobyte of miscellaneous modules and around eight kilobytes of data. This has only grown by around eight kilobytes since OS-9 came to the 68000.

31.3 Application of this Philosophy to User Code

The tools that the kernel uses to build interfaces are available to the other system components. They are, consequently, available to all programs. These facilities (e.g., subroutine modules, data modules, and trap handlers) support OS-9 configurable applications just as they support a configurable operating system.

Small applications that are tightly bound to particular hardware and have have no possibility for other configuration changes, should probably be written as monolithic programs. Programs that are divided into several modules bear a tiny performance penalty. Large, complicated, or volatile programs should be divided into modules. Programs that are carefully divided into modules are much easier to update than monolithic programs. OS-9 forms an excellent practical example of this strategy.

Composite/Structured Design by Glenford J. Myers is a rather old book, but it includes good guidelines for partitioning a program into modules. (Though the book doesn't actually mention modules.)

Trap handlers are an especially convenient tool for partitioning programs. The difference in cost between calling a function and calling a trap handler (see page 201) is large when the functions are trivial, but invisible for a typical C function.

[3] Although it is hard to justify the Julian and Gregorian date-handling code in the OS-9 kernel.

Appendix A

Recent History

This appendix reviews the highlights of the past eight years of OS-9 evolution.

A.1 Version 1.2

OS-9 version 1.2 was released in mid-1985. The kernel featured new system calls for events. RBF and IOMan relaxed the rules for file names to permit letters, numbers, period, underscore, and dollar-sign. The only remaining restriction was that file names must contain at least one letter or number somewhere. Pipeman was extended to support named pipes.

IOMan was merged with the kernel.

The format-inhibit attribute was added to disk device descriptors; so was a sector size field.

SCF added a bunch of modem-control setstats.

`F$STrap` let user programs catch bus errors and address exceptions.

The kernel now tries to expand system tables when they overflow. This lets the system administrator configure the system for a reasonable maximum number of processes and devices without experiencing odd program failures whenever the estimated table sizes are too small.

A.2 Version 2.0

OS-9 version 2.0 was released in late 1986. The big excitement was support for the 68020/68881. The 020 support included the obvious handling for different exception stack formats, also emulation for the `move ccr,ea` instruction, and adjustments of alignments in system data structures to improve performance with the 68020.

System state processes first appeared in version 2.0.

Before version 2.0, signal broadcast reached all processes with no consideration for their group.user. The broadcast facility was also unprotected: any process could broadcast signals. Version 2.0 restricted processes to broadcasting to all processes with their group.user.

Sysdbg appeared, and kernel support for ***debug*** improved.

Security was tightened. In particular, module access permissions are now checked.

The memory allocator was improved. It now merges adjacent blocks in the process memory list. Overflowing the list is much less likely.

Interrupt service routines are expected to save and restore some registers. This gives a big performance improvement. OS-9 was saving and restoring everything even though the typical interrupt service routine only used about three registers.

RBF supports multi-sector I/O and I/O direct from the device to the user's buffer.

The FD segment list of deleted files is not zeroed. This makes an `undelete` utility possible.

A.3 Version 2.1

OS-9 version 2.1 was released in mid-1987. It featured the `F$SigMask` and `F$CCtl` system calls.

These were significant new system calls. `F$SigMask` was an indication that the 2.1 kernel supported signal queuing and masking.

`F$CCtl` resulted from a major restructuring of the kernel. Cache control operations for the 68020 had been inserted in the kernel. This strategy was inadequate. With `F$CCtl`, the kernel can keep all its cache-control code in a separate module. OEMs can now configure OS-9 to take advantage of their external cache without major kernel surgery.

When version 2.1 was released, MMUs for 68020 boards were not common, but version 2.1 included support for an SSM module[1] that would add memory protection for processes.

`F$SetSvc` now allows a static data area to be associated with each system call. Combined with the startup code's new ability to allocate storage for each P2 module and leave the storage allocated after the P2 module returns, version 2.1 gives P2 system calls a way to allocate private static storage.

The "ghost" module attribute was added.

[1] When version 2.1 was released Microware only supported an SSM module for the 68851 MMU coprocessor.

On the 68020, OS-9 uses VBR to locate its system globals and interrupt vectors.

A.4 Version 2.2

OS-9 version 2.2 was released in early 1988 as a maintenance release. All the new stuff since 1.2 was cleaned up in the light of experience. For instance, pipes behave like SCF and RBF when they receive signals. Pipes used to abort when they received a signal. It's also possible to:

```
$ dir –e /pipe
```

I$GetStt SS_Opt now calls the driver. This lets the driver keep track of the path options section more easily.

Timed sleeps are handled by the system process instead of the clock tick IRQ routine, and timed sleep handling is more efficient.

The system ticking variables have been lengthened from 8 bits to 16 bits. This lets the tick rate go above 256 ticks per second.

(The C compiler was greatly enhanced, but that's a different story.)

A.5 Version 2.3

OS-9 version 2.3 was released in mid-1989. It featured F$Alarm, colored memory, and an extensively revised F$CCtl.

The first two features are discussed at length elsewhere in this book. The F$CCtl SVC let the kernel move cache control into a P2 module that could contain an F$CCtl to control any combination of on-chip and off-chip cache.

F$Trans was also added to OS-9. It translates between local addresses and external bus addresses. This is important when an off-board DMA device must reference on-board RAM.

F$Panic was implemented to let a P2 module attempt to recover from conditions that the kernel cannot handle.

The "Universal Disk Format" is first explained in the version 2.3 Release Notes. It is a disk format that should work with any known or likely disk controller

The most remarkable feature of the universal disk format is that it avoids track zero completely. This makes the various behavior of controllers on track zero a non-issue.

A.6 Version 2.4

OS-9 version 2.4 is almost exactly CD-RTOS version 1.1. It was released in late 1990.

Version 2.4 features support for the 683xx chips.

Table A.1: Universal Floppy Disk Format

Device Descriptor Option	**Value**
PD_TotCyls	80
PD_CYL	79
PD_SCT	16
PD_DNS	MFM/96 tpi
PD_SOffs	1
PD_TOffs	1

Table A.2: Processor Support

Version	Processor
2.0	68020
2.2	68030
	68882
2.4	CPU32 family
2.4.2	68040
3.0	Separated

RBF added variable sector size support and caching of disk sectors.

Boot files larger than 64k and non-contiguous boot files are now supported by ***os9gen*** and the boot code.

The kernel's understanding of cache memory is further enhanced.

Incremental releases start here. Microware decided to release software without waiting for grand checkpoints. Too much good stuff (like 68040 support) was being held up by the extreme effort involved in a full OS-9 release.

The first incremental release was version 2.4.2 (early 1991). It introduced initial, and quite tentative, support for the 68040.

Support for the 68040 is improved in version 2.4.3, released in mid-1991. The 68040 runs much faster with copy-back caching turned on. (Though it only works for user code.)

A.7 Discovery Pack

By the end of 1992, OS-9 3.0 was well underway. It looked likely to be a major change for Microware's OEMs, so Microware arranged an official leak.

The Discovery Pack was a preliminary release of 3.0 with the atomic kernel component quite well polished and the development kernel component stable enough to serve as a testing platform, but not ready for complete trust.

A.8 Version 3.0

Version 3.0 was released in fourth-quarter 1993. It marked several major changes for OS-9.

Kernel Explosion Previous releases included two kernels; one supported 16-bit processors, the other supported 32-bit processors. At 3.0 the kernel fragmented into about 32 distinct kernels. There is a family of kernels for each distinguishable processor. Each family includes all four combinations of atomic/development and standard allocator/buddy allocator.

Atomic Kernels The atomic kernel is a major change for Microware. All previous versions added features and size to OS-9. Version 3.0 included the atomic kernel: about as small as OS-9 has ever been and usually faster than any previous version.

New System Calls 3.0 included three new system calls:

1. F$FIRQ is a way to attach an interrupt service routine to an interrupt vector with even less overhead than an F$IRQ. The main constraint is that only one F$FIRQ per vector is permitted.
2. F$SigReset should be called when a signal intercept routine longjmp()s into the mainline. It helps the kernel optimize signal intercept processing.
3. F$Sema is an extra-fast process synchronization system call designed to be called by the semaphore glue routines.

F$SysID The F$SysID has been greatly expanded. Prior to 3.0, F$SysID was implemented but not documented. At version 3.0 it was expanded to rough compatability with the OS–9000 _os_SysID() SVC and made part of the official system interface. It is now the best way to get information about the kernel: the version, the MPU and FPU, and an assortment of other data. It is much better to let OS-dependent code check the kernel version returned by F$SysID than to check the kernel edition number.

Dispatch Routines Dispatch routines involve no new system call. They are implemented with code in OS-9's interrupt epilog. Dispatch routines let an interrupt service routine insert code between the time when interrupts are unmasked and the rte operation that resumes the interrupted activity. It is intended to provide a place for activities that cannot be accomplished in an interrupt service routine but must be done too soon after the ISR to allow time for a normal process activation. Using a dispatch routine is roughly twice as fast as activating a process.

Performance Brief The *Performance Brief* attempts to give programmers enough information about OS-9's performance to be of real use in the design phase. Many of the figures in the brief were generated as internal quality measurements, so they tend to emphasize OS-9's weaknesses; that probably increases their usefulness. The *Performance Brief* is not nearly complete—I suspect it will never be completely finished—but it has a direction. It is pessimistic. For Microware's purposes, the measurements uncover OS-9's weaknesses and measure progress against them. For a programmer, the measurements attempt to indicate what performance can be expected in worst case situations.[2]

System state preemption means performing a context switch out of a process that is currently in system state. This can be quite tricky since processes in system state are generally manipulating system data structures that are shared with other processes. System state preemption opens the door to having several processes executing system calls at the same time. Shared data structures must be protected with some type of locking protocol to prevent corruption.

OS-9 has always allowed interrupt service routines to make almost any system call. This means that the kernel allowed multiple system calls to run concurrently (the one from user state, plus one from each interrupt level). It was a relatively small (and long overdue) step to allow system state preemption.

System state preemption barely affects typical performance, but it improves worst-case performance tremendously. Before system state preemption, the interval from the time an interrupt service routine awakened a process until the process started execution could be the time for the interrupt service routine plus the execution time for any process in system state. Ignoring system state processes, this meant that the execution time for the longest SVC had to be added to the worst case time to activate a process. With system state preemption, SVC execution time is not an issue.

System state preemption was not fully implemented in 3.0. It was disabled in file managers (except SCF and Pipeman) and in all drivers. RBF and PCF used preemption points to improve their worst-case performance.

Performance 3.0 concentrates on interrupt response time and the performance of inter-process-communication mechanisms.

[2] For high-end processors, caches and pipelines make true worst case almost impossible to create. For these processors, the *Brief* contents itself with a range of conditions ranging from almost impossibly good to very bad. The range of performance can reach about one to five.

Appendix B

Technical Appendix

This appendix contains a number of bits of information that did not deserve a chapter of their own or fit into another chapter.

B.1 The Arithmetic of XOR

The effect of an XOR operation on two words is to leave on (i.e., with the bit set to one) only those bits which are on in only one of the two words. For example, if the binary numbers *A* =*%01010110 01101010* and *B* =*%01010101 10101010* were XOR'ed together, the result would be *%00000011 11000000*. Working from the most significant (rightmost) bit to the least significant bit:

The first six bits in *A* and *B* are identical, %010101 in both,
    so the result is 0 for each bit: %000000.
The seventh bit in *A* is 1 and the seventh bit in *B* is 0.
    Since one of them is 1, the result is 1.
The eighth bit in *A* is 0 and the eighth bit in *B* is 1.
    Since one of them is 1, the result is 1.
The ninth bit in *A* is 0 and the ninth bit in *B* is 1.
    Since one of them is 1, the result is 1.
The tenth bit in *A* is 1 and the tenth bit in *B* is 0.
    Since one of them is 1, the result is 1.
The last six bits in *A* and *B* are identical, %101010 in both,
    so the result is 0 for each bit: %000000.

The one's complement operation reverses the state of each bit in a number. Each 1 becomes a 0, and each 0 becomes a 1. If a number is XOR'ed with its one's complement, the result is all 1's:

A	=	%11001101 10101100
Ones complement of A	=	%00110010 01010011
A XOR Complement of A	=	%11111111 11111111

B.2 Bootlist

Os9gen is usually used with a bootlist file:

```
$ os9gen –z=bootlist.h0 /h0
```

The bootlist file contains the list of files that ***os9gen*** should include in the boot file it makes. It is possible, but less common, to type the list of files into ***os9gen***'s standard input, or to redirect its standard input from a bootlist file.

It usually takes a few tries before the bootlist is right, so it is best to make boot files on a floppy or extra hard disk until you have tested it and know that the system will boot correctly with the new boot file. If you replace your working boot file with a broken file, you will have to reconstruct your world rather painfully.

I have two bootlist files that differ mainly in the device they use for initial data and execution directories.

Both of the bootlists shown in figure B.1 are quite fully configured (though I leave the RAM disk descriptor out of the boot file so I can conveniently load a RAM disk of the right size when I need it.) The list labeled bootlist.d0 includes an experimental P2 module and its stb module. Bootlist.h0 includes a descriptor for the default device.

The main difference is that the init module for bootlist.d0 keeps all activity on the /d0.

The boot file described by bootlist.d0 (without the test P2 module) is the bootfile I use on my emergency disk. This is the disk I use to rescue my system when I cannot boot from my hard disk (probably because I broke some important file on /h0). The emergency disk contains everything I need to rescue my system: a boot file that only relies on the one floppy drive, a CMDS directory with enough files in it to get the system going, and a SYS directory with a useful set of files. If the disk has enough space, it is good to add a BOOTOBJS directory with the raw materials to build a new master boot file. Figure B.3 contains a list of the structure of my emergency disk. The .login file and startup file on the emergency disk are as simple as possible. The emergency disk should boot as quickly as possible. Furthermore, there are better ways to use disk space than storing fortunes or other login fluff.

The following is a useful .login suitable for the emergency disk:

Figure B.1: Two Bootlists

Comment	Bootlist.d0	Bootlist.h0
	Kernel	Kernel
	../peter/os9p2	
	../peter/stb/os9p2.stb	
	Init.d0.020	Init.h0.020
	syscache020	syscache020
	m20clk	m20clk
Sequential Block File Manager	Scf	Scf
SCF Drivers and Descriptors		
Serial Driver	sc68681	sc68681
Serial Descriptors	Term	Term
	t1	t1
	t2	t2
	t3	t3
Parallel Driver	sc68230	sc68230
Parallel Descriptor	P	P
Null Driver	Null	Null
Null Descriptor	Nil	Nil
Pipe File Manager	Pipeman	Pipeman
Pipe Descriptor	Pipe	Pipe
Random Block File Manager	Rbf	Rbf
RBF Drivers and Descriptors		
Floppy Disk Driver	rb1772	rb1772
SCSI Disk Driver	rbm20vsl	rbm20vsl
Floppy Disk Descriptors	D0	D0
SCSI Disk Descriptor	h0_vs_4	h0_vs_4
Default Device Descriptor		dd_h0_vs_4
RAM Disk Driver	ram	ram
SBF file manager	sbf	sbf
SBF device driver	sbm20	sbm20
SBF device descriptor	mt0.teac	mt0.teac
Initial System Process	Sysgo	Sysgo

Figure B.2: Two Init Modules

Description	Init.d0.040	Init.h0.040
reserved	0	0
number of irq polling entries	32	32
device table size	32	32
initial process table size	64	64
initial path table size	64	64
startup parameter string		chx cmds; startup
first executable module	Sysgo	shell
default directory name	/D0	/H0
console terminal name	/Term	/Term
customization module list	os9p2 snoop167 syscache ssm fpsp	os9p2 snoop167 syscache ssm fpsp
clock module name	tk167	tk167
ticks per time slice	2	2
reserved	$0000	$0000
site code	0	0
installation name	Myc: Motorola 167	Myc: Motorola 167
cpu type	68040	68040
operating system level	$01030000	$01030000
os-9 revision name	OS-9/68K V3.0	OS-9/68K V3.0
initial system priority	128	128
minimum priority	0	0
maximum age	0	0
module directory size	128	128
reserved	$0000	$0000
initial event table size	32	32
compatability flag #1	$10	$10
compatibility flag #2	$0f	$04
irq stack size (longwords)	256	256
coldstart "chd" retry count	0	0
IOMan module name	IOMan	IOMan
PreIO module list	OS9PreIO	OS9PreIO
system configuration control	$0014	$0014
Number of queued signals (unused)	32	32
Process descriptor stack size	1500	1500

Figure B.3: Directory of an Emergency Disk

```
                     Directory of /D0 01:02:13
.login      CMDS          OS9Boot    SYS        startup
                     Directory of CMDS 01:02:16
attr        break         cio        copy       date
dd_d0       dd_h0         del        devs       dir
dump        emacs         fixmod     format     frestore
link        list          load       login      makdir
math881     mdir          moded      mt0        os9gen
pd          r0            save       sectsize   setime
shell       tape          tmode      tsmon      unlink
utils
                     Directory of SYS 01:02:36
errmsg      moded.fields  motd       password   termcap
termset
```

```
setenv TERM ansi
setenv _sh 0
setenv PROMPT "@$"
setenv PATH /h0/cmds
setenv TZ EST
–e
```

and the minimal startup that I use for my floppy boot disk:

```
–np
–nt
load utils
link shell cio                      ;* make shell and cio stay in memory
setime –s                           ;* read clock & start "ticks"
iniz d0 h0
```

Appendix C

Building a File Manager

Chapter 27 discussed a simple RBF-type file manager. This appendix contains the successor to that file manager. This file manager falls somewhere between a simple example and a serious tool. It illustrates many of the tricks needed to write a real file manager. Regrettably, it also fusses extensively with the PC-DOS disk format.

This file manager[1] reads and writes PC-Dos disks. It even makes them look enough like OS-9 disks that many system utilities work on them. It is definitely *not* a production-quality file manager.

- This program has been tested in ordinary use on several PC-Dos formats with a GMX Micro-20. It may have difficulties with some PC-Dos formats. It will certainly fail with device drivers that have difficulties with 512-byte sectors. The GMX driver simply ignores the sector length. This works unless verify-after-write is requested. Drivers that respect the sector-size field in the device descriptor should work better than drivers that ignore it, but such drivers are uncommon.

- There is no obvious way to detect a new disk in the drive. This file manager doesn't worry about it. Be very cautious if you change disks.

- The file manager creates virtual OS-9 file descriptors, but the simulation is not good enough. Some utilities (e.g., ***pd***, ***dcheck***, and ***deldir***) don't work.

  To delete a directory on an PC-Dos-format disk, follow these steps:

[1] This source code is the proprietary confidential property of Microware Systems Corporation, and is provided to licensee solely for documentation and educational purposes. Reproduction, publication, or distribution in any form to any party other than the licensee is strictly prohibited.

  - Empty the directory.
  - Use the ***attr -nd*** command from the parent directory to remove the directory attribute.
  - Delete the file.

- There is no locking of records or files.
- The file manager seems to handle large numbers of active files, but this is difficult to test.
- There are many ways the I/O performance could be improved.

You do, however, have the source. If you need an additional feature, add it!

Perhaps I have given in slightly to the "It was hard to write. It should be hard to read." policy. Another theory is that this appendix was already long with few comments. In either case, you will probably want to refer to chapter 27 for additional comments.

C.1 Interface to the C File Manager

The OS-9 kernel was written in assembly language, and its interfaces are defined in assembly-language terms. This file manager was written in C with consideration for the limits imposed by the assembly language environment. You won't find any static storage declared in this file. You definitely won't find any initialized statics.

I avoided the standard C libraries because I didn't want to risk a static variable slipping in from the library (errno was a particular problem). Some functions that would normally be library functions are in the fmmain.a file; others are in utils.c; some are even coded in line.

A file manager gets a stack whenever it is called, but it doesn't get stack-size information. Stack-size checking would pose a nasty set of problems, so I didn't do it. Note that the makefile specifies no stack checking.

C.1.1 fmmain.a

Fmmain is the equivalent of cstart. It is the entry point for the file manager. All interfaces that are defined in assembly language are made through the fmmain file.

If you look carefully you will find that this fmmain is a considerably compressed version of the code in chapter 27.

[†]*fmmain*: see page 366

```
                *****************************
                *
                * cstart.a—C program startup routine for a file manager
                *

                         use      <oskdefs.d>
                         opt      –l
00000001  Carry:         equ      %00000001 Carry bit

0000000d  Typ            equ      FlMgr
00000001  Edit           equ      1
00000400  Stk            equ      1024             a default stack size
00000101  Cerror         equ      257              arbitrary C error

                         psect    cstart_a,(Typ<<8)!Objct,(ReEnt<<8)!1,Edit,Stk,_cstart

0000000d  cr             equ      $0d
00000020  space          equ      $20
0000002c  comma          equ      $2c
00000022  dquote         equ      $22
00000027  squote         equ      $27

                *
                * C Program entry point
                *
                * On entry we have:
                * a1 points to the path descriptor
                * a4 points to the current process descriptor
                * a5 points to the user's register stack
                * a6 points to the system global area
                *
                _cstart:
0000 001a                dc.w     _Create–_cstart
0002 0020                dc.w     _Open–_cstart
0004 0026                dc.w     _MakDir–_cstart
0006 002c                dc.w     _ChgDir–_cstart
0008 0032                dc.w     _Delete–_cstart
000a 0038                dc.w     _Seek–_cstart
000c 003e                dc.w     _Read–_cstart
000e 0044                dc.w     _Write–_cstart
0010 005c                dc.w     _ReadLn–_cstart
0012 0062                dc.w     _WriteLn–_cstart
0014 0068                dc.w     _GetStat–_cstart
0016 006e                dc.w     _SetStat–_cstart
0018 0074                dc.w     _Close–_cstart

                _Create
001a=41fa                lea.l    Create(pc),a0                                  /* pg. 543 */
001e 6028                bra.s    fmCommon
```

```
                _Open
0020=41fa       lea.l   Open(pc),a0                              /* pg. 539 */
0024 6022       bra.s   fmCommon

                _MakDir
0026=41fa       lea.l   MakDir(pc),a0                            /* pg. 544 */
002a 601c       bra.s   fmCommon

                _ChgDir
002c=41fa       lea.l   ChgDir(pc),a0                            /* pg. 549 */
0030 6016       bra.s   fmCommon

                _Delete
0032=41fa       lea.l   Delete(pc),a0                            /* pg. 548 */
0036 6010       bra.s   fmCommon

                _Seek
0038=41fa       lea.l   Seek(pc),a0                              /* pg. 550 */
003c 600a       bra.s   fmCommon

                _Read
003e=41fa       lea.l   Read(pc),a0                              /* pg. 529 */
0042 6004       bra.s   fmCommon

                _Write
0044=41fa       lea.l   Write(pc),a0                             /* pg. 533 */

                fmCommon
0048 48e7       movem.l a4/a6,-(sp)
004c 2009       move.l  a1,d0
004e 220d       move.l  a5,d1
0050 4e90       jsr     (a0)           (pd, regs, ProcDesc, SysGlobs)
0052 4cdf       movem.l (sp)+,a4/a6
0056 4a40       tst.w   d0
0058 6620       bne.s   _Error
005a 4e75       rts

                _ReadLn
005c=41fa       lea.l   ReadLn(pc),a0                            /* pg. 531 */
0060 60e6       bra.s   fmCommon

                _WriteLn
0062=41fa       lea.l   WriteLn(pc),a0                           /* pg. 536 */
0066 60e0       bra.s   fmCommon

                _GetStat
0068=41fa       lea.l   GetStat(pc),a0                           /* pg. 550 */
006c 60da       bra.s   fmCommon
```

```
          _SetStat
006e=41fa          lea.l    SetStat(pc),a0                              /* pg. 551 */
0072 60d4          bra.s    fmCommon

          _Close
0074=41fa          lea.l    Close(pc),a0                                /* pg. 547 */
0078 60ce          bra.s    fmCommon

          _Error
007a 3200          move.w   d0,d1
007c 003c          ori      #Carry,ccr
0080 4e75          rts

          *        CallRead (ct, lsn, pd, DevStaticS, ProcD, regs, sysglobs)
          * puts
          *        ct in d0
          *        lsn in d2
          *        pd in a1
          *        DevStaticS in a2
          *        ProcD in a4
          *        regs in a5
          *        sysglobs in a6
          CallRead:
0082 48e7          movem.l d2–d7/a0–a5,–(sp)
          * ct is already in d0
          * calculate the entry address in the device driver
0086 226f          move.l   13*4(sp),a1       pd to a1
008a=2069          move.l   PD_DEV(a1),a0     device table entry
008e=2068          move.l   V$DRIV(a0),a0     device driver address
0092=2428          move.l   M$Exec(a0),d2     device driver entry offset
0096=d0f0          add.w    D$READ(a0,d2),a0 add read-entry offset to module base

009a 2401          move.l   d1,d2
009c 246f          move.l   14*4(sp),a2       DevStatic to a2
00a0 286f          move.l   15*4(sp),a4       ProcD to a4
00a4 2a6f          move.l   16*4(sp),a5       regs to a5
          * sysglobs is already in a6

00a8 4e90          jsr      (a0)
00aa 6534          bcs.s    CallError
00ac 602a          bra.s    CallOK

          * CallWrite (ct, lsn, pd, DevStaticS, ProcD, regs, sysglobs)
          * puts
          *        ct in d0
          *        lsn in d2
          *        pd in a1
          *        DevStaticS in a2
```

```
           *          ProcD in a4
           *          regs in a5
           *          sysglobs in a6
           CallWrite:
00ae 48e7             movem.l d2–d7/a0–a5,–(sp)
           * ct is already in d0
00b2 226f             move.l   13*4(sp),a1 pd to a1
           * calculate the entry address in the device driver
00b6=2069             move.l   PD_DEV(a1),a0  device table entry
00ba=2068             move.l   V$DRIV(a0),a0   device driver address
00be=2428             move.l   M$Exec(a0),d2   device driver entry offset
00c2=d0f0             add.w    D$WRIT(a0,d2),a0 add read-entry offset to module base

00c6 2401             move.l   d1,d2             lsn to d2
00c8 246f             move.l   14*4(sp),a2       DevStatic to a2
00cc 286f             move.l   15*4(sp),a4       ProcD to a4
00d0 2a6f             move.l   16*4(sp),a5       regs to a5
           * sysglobs is already in a6
00d4 4e90             jsr      (a0)
00d6 6508             bcs.s    CallError

           CallOK
00d8 4cdf             movem.l (sp)+,d2–d7/a0–a5
00dc 4280             clr.l    d0
00de 4e75             rts

           CallError
00e0 2001             move.l   d1,d0
00e2 4cdf             movem.l (sp)+,d2–d7/a0–a5
00e6 4e75             rts

           * CallGetStat(code, pd, DevStaticS, procd, regs, sysglobs)
           * puts
           *          code in d0
           *          pd in a1
           *          DevStaticS in a2
           *          ProcD in a4
           *          regs in a5
           *          sysglobs in a6
           CallGetStat:
00e8 48e7             movem.l d2–d7/a0–a5,–(sp)
           * code is already in d0
00ec 2241             move.l   d1,a1             pd to a1
           * calculate the entry address in the device driver
00ee=2069             move.l   PD_DEV(a1),a0  device table entry
00f2=2068             move.l   V$DRIV(a0),a0   device driver address
00f6=2428             move.l   M$Exec(a0),d2   device driver entry offset
00fa=d0f0             add.w    D$GSTA(a0,d2),a0 add read-entry offset to module base
```

```
00fe 246f           move.l  13*4(sp),a2      DevStatic to a2
0102 286f           move.l  14*4(sp),a4      ProcD to a4
0106 2a6f           move.l  15*4(sp),a5      regs to a5
          * sysglobs is already in a6
010a 4e90           jsr     (a0)
010c 65d2           bcs.s   CallError
010e 60c8           bra.s   CallOK

          * CallSetStat(code, pd, DevStaticS, procd, regs, sysglobs)
          * puts
          *         code in d0
          *         pd in a1
          *         DevStaticS in a2
          *         ProcD in a4
          *         regs in a5
          *         sysglobs in a6
          CallSetStat:
0110 48e7           movem.l d2–d7/a0–a5,–(sp)
          * code is already in d0
0114 2241           move.l  d1,a1            pd to a1
          * calculate the entry address in the device driver
0116=2069           move.l  PD_DEV(a1),a0  device table entry
011a=2068           move.l  V$DRIV(a0),a0  device driver address
011e=2428           move.l  M$Exec(a0),d2  device driver entry offset
0122=d0f0           add.w   D$PSTA(a0,d2),a0 add read-entry offset to module base

0126 246f           move.l  13*4(sp),a2      DevStatic to a2
012a 286f           move.l  14*4(sp),a4      ProcD to a4
012e 2a6f           move.l  15*4(sp),a5      regs to a5
          * sysglobs is already in a6
0132 4e90           jsr     (a0)
0134 65aa           bcs.s   CallError
0136 60a0           bra.s   CallOK

          _srqmem:
0138 2f0a           move.l  a2,–(sp)
013a=4e40           os9     F$SRqMem
013e 6404           bcc.b   srqmemx1
0140 70ff           moveq.l #–1,d0
0142 6002           bra.b   srqmemx
          srqmemx1
0144 200a           move.l  a2,d0
          srqmemx
0146 245f           move.l  (sp)+,a2
0148 4e75           rts

          *
          *         DoIOQ(processid)
          *
```

```
              DoIOQ:
014a=4e40                os9      F$IOQu
014e 2001                move.l   d1,d0            return code
0150 4e75                rts

              *
              *          DoSRtMem(ptr, size)
              *
              DoSRtMem:
0152 2f0a                move.l   a2,-(sp)
0154 2440                move.l   d0,a2
0156 2001                move.l   d1,d0
0158=4e40                os9      F$SRtMem
015c 6404                bcc.b    DoSrtMx
015e=4e40                os9      F$SysDbg
              DoSrtMx
0162 245f                move.l   (sp)+,a2
0164 4e75                rts

              SysDebug:
0166=4e40                os9      F$SysDbg
016a 4e75                rts

              GetUser:
016c 2f02                move.l   d2,-(sp)
016e=4e40                os9      F$ID
0172 241f                move.l   (sp)+,d2
0174 2001                move.l   d1,d0
0176 4e75                rts

              GetDate:
0178 48e7                movem.l d0-d2/a0,-(sp)
017c 7000                moveq    #0,d0            Gregorian
017e=4e40                os9      F$Time
0182 2057                move.l   (sp),a0          get the pointer from d0
0184 2401                move.l   d1,d2
0186 4242                clr.w    d2
0188 4842                swap     d2
018a 84fc                divu.w   #100,d2
018e 4842                swap     d2               put the remainder in the low-order word
0190 10c2                move.b   d2,(a0)+         save YY
0192 e159                rol.w    #8,d1            Move MM into position
0194 10c1                move.b   d1,(a0)+         save MM
0196 e159                rol.w    #8,d1            Move DD into position
0198 10c1                move.b   d1,(a0)+         save DD
019a e198                rol.l    #8,d0
019c e198                rol.l    #8,d0            Move HH into position
019e 10c0                move.b   d0,(a0)+         save HH
01a0 e198                rol.l    #8,d0            Move MM into position
```

```
01a2 1080            move.b   d0,(a0)           save MM
01a4 4cdf            movem.l (sp)+,d0–d2/a0
01a8 4e75            rts

            * MoveData(dest, src, length)
            MoveData:
01aa 48e7            movem.l d2/a0/a2,−(sp)
01ae 2440            move.l   d0,a2             destination
01b0 2041            move.l   d1,a0             source
01b2 242f            move.l   4*4(sp),d2        length
01b6 7200            moveq.l #0,d1              sweep for error code
01b8=4e40            os9      F$Move
01bc 2001            move.l   d1,d0             move error code to d0
01be 4cdf            movem.l (sp)+,d2/a0/a2
01c2 4e75            rts
000001c4             ends
```

C.1.2 Makefile

```
# Make file to produe MSDos disk file manager
LIB       =        /dd/lib/sys.l
DEBUG     =        −g
CFLAGS = −r −tp020 −td=/r0 −w=.
IFILES = msfm.i msopen.i ReadSector.i drivetable.i MakDir.i\
            Read.i ReadLn.i Close.i FATSupport.i Create.i Delete.i\
            dir.i utils.i TransDir.i GetFD.i Write.i WriteLn.i WriteSector.i

RFILES = fmmain.r alli.r

all: msfm msD0

msfm: alli.r fmmain.r
            l68 −l=/dd/lib/clib.l $(DEBUG) −l=$(LIB) $(RFILES) −o=msfm

alli.r: $(IFILES)
            cc −eas $(CFLAGS) −fd=alli.r $(IFILES)

fmmain.r: fmmain.a
            r68 fmmain.a −o=fmmain.r

msD0:       DevDesc.r
            l68 DevDesc.r −l=/dd/lib/sys.l −o=msD0

msfm.i: msfm.c format.h PathDesc.h
            cc −efe $(CFLAGS) msfm.c

msopen.i: msopen.c format.h PathDesc.h
            cc −efe $(CFLAGS) msopen.c
```

```
DevDesc.r: DevDesc.a
        r68 DevDesc.a –o=DevDesc.r

ReadSector.i: ReadSector.c format.h PathDesc.h
        cc –efe $(CFLAGS) ReadSector.c

drivetable.i: drivetable.c format.h PathDesc.h
        cc –efe $(CFLAGS) drivetable.c

Read.i: Read.c format.h PathDesc.h
        cc –efe $(CFLAGS) Read.c

ReadLn.i: ReadLn.c format.h PathDesc.h
        cc –efe $(CFLAGS) ReadLn.c

Close.i: Close.c format.h PathDesc.h
        cc –efe $(CFLAGS) Close.c

FATSupport.i: FATSupport.c format.h PathDesc.h
        cc –efe $(CFLAGS) FATSupport.c

dir.i: dir.c format.h PathDesc.h
        cc –efe $(CFLAGS) dir.c

utils.i: utils.c
        cc –efe $(CFLAGS) utils.c

TransDir.i: TransDir.c
        cc –efe $(CFLAGS) TransDir.c

GetFD.i: GetFD.c
        cc –efe $(CFLAGS) GetFD.c

Create.i: Create.c
        cc –efe $(CFLAGS) Create.c

WriteSector.i: WriteSector.c format.h PathDesc.h
        cc –efe $(CFLAGS) WriteSector.c

Write.i: Write.c format.h PathDesc.h
        cc –efe $(CFLAGS) Write.c

WriteLn.i: WriteLn.c format.h PathDesc.h
        cc –efe $(CFLAGS) WriteLn.c

Delete.i: Delete.c format.h PathDesc.h
        cc –efe $(CFLAGS) Delete.c
```

```
MakDir.i: MakDir.c format.h PathDesc.h
          cc –efe $(CFLAGS) MakDir.c
```

C.2 Main Entry Points

Each file manager function has a corresponding C function. These functions are for the most part generic, and should work with small changes for any RBF-style file system.

C.2.1 Read.c

There is an extensive *if* statement near the end of the Read() function. The *if* statement deals with an odd feature of the PC-Dos root directory. Unlike all other PC-Dos directories, the root directory doesn't have `.` and `..` entries. OS-9 doesn't like that at all, so the Read() and Readln() functions insert `.` and `..` entries at the beginning of the root directory.

```
#include <errno.h>
#include <procid.h>
#include <modes.h>
typedef char *POINTER;
#include "format.h"
#include "PathDesc.h"

Read(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    u_int16 PartialLength;
    u_int16 Sector, offset;
    int32 length;
    char *dest;
    int ReturnVal=0;

    if((pd->PD_Accs & S_IREAD) == 0)
        return(E_BMODE);

    length = regs->R_d1;
    dest = regs->R_a0;

    if((length + pd->PD_CP) >= pd->PD_SIZ)
        if(pd->PD_CP >= pd->PD_SIZ)
            return E_EOF;
        else
```

[†] *read*: see page 375

```
            length = regs→R_d1 = (pd→PD_SIZ – pd→PD_CP);

    offset = OffsetInSector(pd);                                    /* pg. 530 */

    while(length >0){
        /*Now prepare to read a sector  */
        if((Sector = CheckSector(pd)) >= (T_FAT_BADTRACK)){         /* pg. 577 */
            ReturnVal = Errno(Sector);                              /* pg. 573 */
            break;
        }
        if((ReturnVal = ReadSector(pd, Sector, pd→PD_BUF,           /* pg. 562 */
                regs, procd, SysGlobs)) != 0)
            break;

        /*
            At least part of this sector should be copied to the caller's buffer.  The
            "interesting" data starts at offset from the beginning of the sector and
            continues for length bytes, or to the end of the sector (whichever is
            least).
        */
        PartialLength = SECTORSIZE – offset;
        if(PartialLength > length)
            PartialLength = length;
        length -= PartialLength;


        /*
            Copy the data to the caller's buffer
        */
        if((pd→PD_SMF & PD_DIR_MODE) &&
                !(pd→PD_SMF & PD_RAWMODE) &&
                (pd→PD_CP < (2 * sizeof(MSDirEntry))) &&
                (Sector == MS_SECTOR(pd→PD_DTB→DD_DIR)))
            pd→PD_CP = FakeRootDir(pd→PD_CP, &PartialLength, &dest);   /* pg. 571 */

        pd→PD_CP += PartialLength; /*Update cur. position in pd  */
        MoveData(dest, pd→PD_BUF+offset, PartialLength);             /* pg. 527 */
        dest += PartialLength;
        offset = 0;
    }
    return ReturnVal;
}


int OffsetInSector(PD_TYPE pd)
```

```
{
    if((pd→PD_SMF & PD_DIR_MODE) &&
            !(pd→PD_SMF & PD_RAWMODE) &&
            (pd→PD_SMF & PD_RDIR_MODE))
        if(pd→PD_CP <= (2 * sizeof(MSDirEntry)))
            return(pd→PD_CP & 31); /*note that sizeof msdirentry = 32 */
        else
            return((pd→PD_CP – (2 * sizeof(MSDirEntry))) & (SECTORSIZE – 1));

    return (pd→PD_CP & (SECTORSIZE –1));
}
```

C.2.2 ReadLn.c

The ReadLn( ) function resembles the Read( ) function. It must, however, transfer bytes one at a time while looking for the end-of-line character.

ReadLn( ), like Read( ), generates fake entries for the root directory.

```
#include <errno.h>
#include <procid.h>
#include <modes.h>
typedef char *POINTER;
#include "format.h"
#include "PathDesc.h"

int ReadLn(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    unsigned long length;
    ushort i, j;
    register unsigned long Sector, offset;
    char *dest, *ptr;
    int ReturnVal=0;
    int eol;

    if((pd→PD_Accs & S_IREAD) == 0)
        return(E_BMODE);

    length = regs→R_d1;
    dest = regs→R_a0;
    regs→R_d1 = 0;

    if((length + pd→PD_CP) >= pd→PD_SIZ)
```

† *readln*: see page 379

```
    if(pd→PD_CP >= pd→PD_SIZ)
        return E_EOF;
    else
        length = (pd→PD_SIZ – pd→PD_CP);

offset = OffsetInSector(pd);                                    /* pg. 530 */

eol = FALSE;
while((length > 0) && !eol){
    /*Now prepare to read a sector */
    if((Sector = CheckSector(pd)) >= T_FAT_BADTRACK){           /* pg. 577 */
        ReturnVal = Errno(Sector);                              /* pg. 573 */
        break;
    }
    if((ReturnVal = ReadSector(pd, Sector, pd→PD_BUF,          /* pg. 562 */
            regs, procd, SysGlobs)) != 0)
        break;

    /*
        At least part of this sector should be copied to the caller's buffer. The
        "interesting" data starts at offset from the beginning of the sector and
        continues for length bytes, or to the end of the sector (whichever is
        least).
    */
    i = SECTORSIZE – offset;
    if(i > length)
        i = length;

    /*
        Copy the data to the caller's buffer
    */
    if((pd→PD_SMF & PD_DIR_MODE) &&
            !(pd→PD_SMF & PD_RAWMODE) &&
            (pd→PD_CP < (2 * sizeof(MSDirEntry))) &&
            (Sector == pd→PD_DTB→DD_DIR))
        pd→PD_CP = FakeRootDir(pd→PD_CP, &i, &dest);           /* pg. 571 */

    for(ptr = pd→PD_BUF+offset, j=0 ; j<i ; ++j)
        if(*ptr != pd→PD_NewLine)
            *dest++ = *ptr++;
        else{
            *dest++ = '\n';
            eol = TRUE;
            ++j;
            break;
            }
        length -= j;
        pd→PD_CP += j; /*Update current position in pd */
        regs→R_d1 += j; /*Update the amount read */
        offset = 0;
    }
    return ReturnVal;
}
```

C.2.3 Write.c

Ordinary data is written without excitement. Directory entries require special processing. PC-Dos hides what amounts to a file descriptor in each directory entry. The file manager must not allow OS-9 utilities (e.g., ***rename***) to obliviously write directory entries. They could easily destroy file descriptor information. Write() and WriteLn() note directory writes and use a special function that protects and reconstitutes PC-Dos file information.

```
#include <errno.h>
#include <procid.h>
#include <modes.h>
typedef char *POINTER;
#include "format.h"
#include "PathDesc.h"

int Write(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    int32 length;
    u_int16 PartialLength, offset;
    u_int32 Sector;
    char *from;
    int ReturnVal=0;

    if((pd→PD_Accs & S_IWRITE) == 0)
        return E_BMODE;

    length = regs→R_d1;
    from = regs→R_a0;


    if(pd→PD_CP + length > pd→PD_SIZ)
        SetFileSize(pd, pd→PD_CP + length);                               /* pg. 535 */
```

[†] *write*: see page 379

```
if((Sector = WritePrepare(pd,1)) >= T_FAT_BADTRACK)              /* pg. 535 */
    return(E_FULL);

offset = OffsetInSector(pd);                                     /* pg. 530 */

while(length >0){
    /*
         At least part of this sector should be updated. The “interesting” data
        *starts at offset from the beginning of the sector and continues for length
         bytes, or to the end of the sector (whichever is least).
    */
    PartialLength = SECTORSIZE – offset;
    if(PartialLength > length)
        PartialLength = length;
    length -= PartialLength;
    /*
        Adjust the file length if necessary
    */
    if((Sector = WritePrepare(pd, PartialLength)) >= T_FAT_BADTRACK)  /* pg. 535 */
        return(E_FULL);

    /*
        Copy the data from the caller’s buffer
    */
    RawReadSector(pd, Sector, pd→PD_BUF, regs, procd, SysGlobs);      /* pg. 562 */
    pd→PD_CP += PartialLength; /*Update cur. position in pd */
    if(pd→PD_SMF & PD_DIR_MODE) {
        if(WriteIntoDir(offset, PartialLength,                         /* pg. 571 */
                pd→PD_BUF+offset, from) != 0)
            return –1; /*ad hoc error msg */
    }else{
        MoveData(pd→PD_BUF+offset, from, PartialLength);               /* pg. 527 */
        from += PartialLength;
    }

    if((ReturnVal = WriteSector(pd, Sector, pd→PD_BUF,                 /* pg. 564 */
            regs, procd, SysGlobs)) != 0)
        break;
    offset = 0;
}
if(ReturnVal == 0)
    if(pd→PD_CP > pd→PD_SIZ)
        return SetFileSize(pd, pd→PD_CP);                              /* pg. 535 */
return ReturnVal;
```

```
}


int SetFileSize(PD_TYPE pd, u_int32 length)
{
    register int RVal;

    if((RVal = FATSetFileLength(pd, length)) == 0)                    /* pg. 576 */
        DirSetFileLength(pd, length);                                 /* pg. 559 */
    return Errno(RVal);                                               /* pg. 573 */
}


int WritePrepare(PD_TYPE pd, u_int16 length)
{
    register ulong Sector;
    register ulong n;

    if(pd→PD_SMF & PD_DIR_MODE)
        return W_PrepareDir(pd, length);                              /* pg. 535 */
    else{
        n = SectorInFile(pd→PD_CP, pd→PD_SMF);                        /* pg. 577 */
        if((Sector = SectorOnDisk(pd, n)) >= (T_FAT_BADTRACK))        /* pg. 578 */
            if(Errno(Sector) == E_EOF)                                /* pg. 573 */
                if(FATSetFileLength(pd, pd→PD_SIZ) != 0)              /* pg. 576 */
                    return T_FAT_LASTSECTOR;
                else
                    Sector = SectorOnDisk(pd, n);                     /* pg. 578 */
        if(pd→PD_CP > pd→PD_SIZ)
            DirSetFileLength(pd, pd→PD_CP);                           /* pg. 559 */

        return(Sector);
    }
}


int W_PrepareDir(PD_TYPE pd, u_int16 length)
{
    u_int32 Sector;
    u_int32 n;

    n = SectorInFile(pd→PD_CP, pd→PD_SMF);                            /* pg. 577 */
    if((Sector = SectorOnDisk(pd, n)) >= (T_FAT_BADTRACK))            /* pg. 578 */
        if(Errno(Sector) == E_EOF)                                    /* pg. 573 */
            if(FATSetFileLength(pd, pd→PD_CP+length) != 0)            /* pg. 576 */
                return T_FAT_LASTSECTOR;
            else
                Sector = SectorOnDisk(pd, n);                        /* pg. 578 */
    return(Sector);
}
```

C.2.4 WriteLn.c

WriteLn() operates under the foolish assumption that nobody will use I$WritLn to update a directory entry. It doesn't check for directory-write mode.

```
#include <errno.h>
#include <procid.h>
#include <modes.h>
typedef char *POINTER;
#include "format.h"
#include "PathDesc.h"

int WriteLn(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    u_int32 length, i, j;
    u_int32 Sector;
    u_int16 offset;
    char *from, *ptr;
    int ReturnVal=0;
    int eol;

    if((pd→PD_Accs & S_IWRITE) == 0)
        return E_BMODE;

    length = regs→R_d1;
    from = regs→R_a0;
    regs→R_d1 = 0;


    if(pd→PD_CP + length > pd→PD_SIZ)
        SetFileSize(pd, pd→PD_CP + length);                      /* pg. 535 */

    if((Sector = WritePrepare(pd, 1)) >= T_FAT_BADTRACK)         /* pg. 535 */
        return(E_FULL);
    offset = OffsetInSector(pd);                                 /* pg. 530 */
```

† *write*: see page 379

```
    eol = FALSE;
    while((length >0) && !eol){
        /*
            At least part of this sector should be updated from the caller's buffer.
            The "interesting" data starts at offset from the beginning of the sector
            and continues for length bytes, or to the end of the sector (whichever
            is least).
        */
        i = SECTORSIZE – offset;
        if(i > length)
            i = length;

        if((Sector = WritePrepare(pd, i)) >= T_FAT_BADTRACK)              /* pg. 535 */
            return(E_FULL);
        RawReadSector(pd, Sector, pd→PD_BUF, regs, procd, SysGlobs);      /* pg. 562 */

        /*
            *Copy the data from the caller's buffer
        */

        for(ptr = pd→PD_BUF+offset, j=0 ; j < i ; ++j)
            if(*from != pd→PD_NewLine)
                *ptr++ = *from++;
            else{
                *ptr++ = '\n';
                eol = TRUE;
                ++j;
                break;
            }
        length -= j;
        pd→PD_CP += j;          /*Update current position in pd */
        regs→R_d1 += j;         /*Update the amount written */
        if((ReturnVal = WriteSector(pd, Sector, pd→PD_BUF,                /* pg. 564 */
                regs, procd, SysGlobs)) != 0)
            break;

        offset = 0;
    }
    if(ReturnVal == 0)
        if(pd→PD_CP > pd→PD_SIZ)
            return SetFileSize(pd, pd→PD_CP);                             /* pg. 535 */

    return ReturnVal;
}
```

C.2.5 MsOpen.c

The MsOpen.c file contains the open() function and a number of closely-related service functions. The Open() function serves the I$Open SVC. The FindFile() function is used by Open(), and all the functions that initialize a path descriptor (e.g., Create(), Delete(), and Makdir()).

FindFile initializes a path descriptor as far as it can without binding it to a file. When preliminary initialization is finished, FindFile() parses the file name and locates it on the disk. It finishes by checking for protection violations and setting the file's access mode.

The outline of FindFile() is:

```
if file-name-independent path initialization succeeds
    write the FAT cached in device static storage
    if Reset the drive table entry is successful
        if Reload of the FAT is successful
            if the file name is valid
                find it on the disk
            if the file is found
                if the caller has access rights
                    set the file access mode
                    return success
```

When this function is called by Create() or MakDir()—functions that need not find the file they are trying to open—it returns a path descriptor that is initialized as far as putting the parsed file name into the path descriptor, and an error code describing its failure mode. When it is called by Open(), it returns a fully initialized path descriptor.

The name-parsing rules used by ParseName() are more rigid than necessary. PC-DOS does not restrict file names to alphanumeric characters.

```
#include <errno.h>
#include <procid.h>
#include <modes.h>
typedef char *POINTER;
#include "format.h"
#include "PathDesc.h"

#define OS9_WRITE 0x02
#define OS9_DIR 0x080

static char *CopyFName(u_char *, char *);
```

†*open*: see page 373

```
static char *CopyToken(u_char *, char *, u_int16);
static char *GetName(PD_TYPE, char *, int *);

int Open(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    int RVal;

    if(pd→PD_CNT >1) return 0;          /* The path's already open.   */

    if((RVal = FindFile(pd, regs, procd, SysGlobs)) != 0)             /* pg. 539 */
        Close(pd, regs, procd, SysGlobs);                             /* pg. 547 */
    return RVal;
}


int FindFile(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    register int RVal;

    if((RVal = InitPD(pd)) == 0){                                     /* pg. 539 */
        FlushDevice(pd, procd, SysGlobs);                             /* pg. 580 */
        if((RVal = ReadSector(pd, 0, pd→PD_BUF, regs, procd, SysGlobs)) == 0)/* pg. 562 */
            if((RVal = ReadFAT(pd, regs, procd, SysGlobs)) == 0)      /* pg. 578 */
                if((RVal = ParseName(pd, regs, procd, SysGlobs)) == 0)  /* pg. 540 */
                    if((RVal = CheckSecurity(pd, (uchar)regs→R_d0)) ==0)  /* pg. 541 */
                        pd→PD_Accs = regs→R_d0;
    }
    return RVal;
}


/*
    Initialize the path descriptor.
*/
int InitPD(PD_TYPE pd)
{
    if((pd→PD_BUF = (char *)_srqmem(SECTORSIZE)) == (char *)−1)       /* pg. 525 */
        return E_MEMFUL;
    if((pd→PD_FDBUF = (MSDirE)_srqmem(SECTORSIZE)) == (MSDirE)−1)/* pg. 525 */
        return E_MEMFUL;

    pd→PD_DVT = (POINTER)pd→PD_DEV;
    pd→PD_SMF = 0;
    pd→PD_DTB = &(pd→PD_DEV→V_STAT→V_DRIVES[pd→PD_DRV]);
    pd→PD_CP = 0;          /*current offset in file  */
    pd→PD_Accs = S_IREAD | S_IFDIR;

    return 0;
}



/*
    Get the file name from *R_a0,
    Ensure that it is in the msdos name.ext form and put the resulting
    name/extension into PD_Name.
*/

int ParseName(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    register char *Name;
    register char *NextName;
    int RVal;
    boolean InTree;
    char Delim;

    NextName = regs→R_a0;
    if((Delim = *NextName) == PATHDELIM)
        ++NextName;

    InTree = FALSE;
    RVal = 0;

    do {
        Name = NextName;
        if((NextName = GetName(pd, Name, &RVal)) == NULL)              /* pg. 541 */
            return RVal;

        if(!InTree){
            InTree = TRUE;
            SetRootDir(pd, procd, Delim);                              /* pg. 555 */
            if((RVal = CheckAccess(pd, regs→R_d0)) != 0)               /* pg. 541 */
                break;
            if(Delim == PATHDELIM)
                continue;
        }

        if((RVal = DirLookup(pd, regs, procd, SysGlobs)) == 0){        /* pg. 553 */
            if((RVal = CheckAccess(pd, regs→R_d0)) == 0)               /* pg. 541 */
                continue;
        }else if(RVal == E_EOF)
```

```
            RVal = E_PNNF;

        return RVal;
    }while(*NextName > ' ');


    regs→R_a0 = NextName;
    return 0;
}


int CheckAccess(PD_TYPE pd, u_int32 AccessMode)
{
    /*if rawmode only give superuser write access */
    /*Everyone gets read access through the end of the root directory */
    if((pd→PD_SMF & PD_RAWMODE) && (AccessMode & OS9_WRITE)){
        if(GetUser( ) == 0)                                          /* pg. 526 */
            return 0;
        else
            return E_FNA;
    }
    return 0;
}


int CheckSecurity(PD_TYPE pd, u_char mode)
{
    register uchar x;

    if(!(pd→PD_SMF & PD_RAWMODE) &&
            ((pd→PD_SMF & PD_DIR_MODE) || (mode & S_IFDIR)) &&
            !((pd→PD_SMF & PD_DIR_MODE) && (mode & S_IFDIR)))
        return E_FNA;
    x = pd→PD_ATT & (S_IFDIR | S_IWRITE | S_IREAD);
    if((x | mode) != x)        /*no public/private distinction */
        return E_FNA;
    return 0;
}


static char *GetName(PD_TYPE pd, char *Name, int *RVal)
{
    *pd→PD_Name = '\0';        /*Initialize */

    Name = CopyFName(pd→PD_Name, Name);                              /* pg. 543 */
    if(islegal(*Name)){          /*names more than 8 chars long are bad */          /* pg. 560 */
        *RVal = E_BPNAM;
        return(NULL);
    }

    if(strcmp(pd→PD_Name, "..") == 0)
        return Name;          /*Stop after .. */

    if(*Name == '.'){          /*Non-null extension */
        Name = CopyToken(pd→PD_Name, Name, 4);                                  /* pg. 542 */
        if(islegal(*Name)){          /*extensions more than 3 chars long are bad */ /* pg. 560 */
            *RVal = E_BPNAM;
            return(NULL);
        }
    }

    switch(*Name){
        case ENTIRE_DELIM:
                pd→PD_SMF |= PD_RAWMODE;
                /*Fall through intensionally */
        case PATHDELIM:
                ++Name;
                break;
        default:
                break;
    }

    return Name;
}


static char *CopyToken(u_char *to, char *from, u_int16 length)
{
    while(*to) ++to;          /*skip to 0 */

    if(*from == '.'){
        *to++ = *from++;
        length––;
    }

    for(; length >0; length––)
    if(islegal(*from))
        *to++ = toupper(*from++);                                                /* pg. 560 */
    else
        *to++ = '\0';
    *to = '\0';
    return from;
}


static char *CopyFName(u_char *to, char *from)
{
    int length=8;

    if(*from == PATHDELIM)
        ++from;
    if(*from == '.'){                   /*One dot */
        *to++ = *from++;
        length--;
        if(*from == '.'){                   /*Two dots */
            *to++ = *from++;
            length--;
            if(*from == '.'){                   /*More dots */
                *to = '\0';
                return (from - 1);
            }
        }
        *to = '\0';
    }

    return CopyToken(to, from, length);                                   /* pg. 542 */
}
```

C.2.6 Create.c

```
#include <errno.h>
#include <procid.h>
#include <modes.h>

typedef char *POINTER;

#include "format.h"
#include "PathDesc.h"

int Create(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
```

† *create*: see page 378

```
    int RVal;

    switch(RVal = FindFile(pd, regs, procd, SysGlobs)){
        case E_PNNF: /*A new file.  We can create it  */
            /*Build a directory entry.   */
            if(regs→R_d1 & S_IFDIR) /*a directory  */
                pd→PD_SMF |= PD_DIR_MODE;
            RVal = MakDirEntry(pd, regs, procd, SysGlobs)                    /* pg. 557 */;
            break;
        case 0: /*An old file that we can access.   */
            /*Empty it and return as if we just opened  */
            RVal = SetFileSize(pd, 0);                                       /* pg. 535 */
            break;
        default:        /*Probably not accessible.  Return the error code  */
            break;
    }
    if(RVal){
        CLEANFD(pd);        /*Don't update the fd for this file  */
        Close(pd, regs, procd, SysGlobs);                                    /* pg. 547 */
    }
    return RVal;
}
```

C.2.7 MakDir.c

PC-Dos directories are allocated a sector at a time. They don't have a specified length, so the directory sectors must be initialized with null directory entries when they are allocated.

```
#include <errno.h>
#include <procid.h>
#include <modes.h>
typedef char *POINTER;
#include "format.h"
#include "PathDesc.h"

#define INIT_DIR_SIZE(pd) ((pd)→PD_SAS*2*(pd)→PD_DTB→DD_SPC)

MakDir(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    int RVal;
    u_int16 i;
```

†*makdir*: see page 377

```
uchar *ptr;
REGISTERS RegsCopy;
MSDirEntry DirEntry;

/*
    Create the file in directory mode
*/

RegsCopy = *regs;
RegsCopy.R_d1 |= S_IFDIR;          /*make this create into directory mode */
RegsCopy.R_d0 |= S_IWRITE;

if((RVal = Create(pd, &RegsCopy, procd, SysGlobs)) != 0)         /* pg. 543 */
    return RVal;
regs→R_a0 = RegsCopy.R_a0;

if(FATSetFileLength(pd, (ulong)(INIT_DIR_SIZE(pd)*SECTORSIZE)) >= /* pg. 576 */
        FAT_BADTRACK)
    RVal = E_FULL;          /*media full */
else
    RVal = 0;


/*
    Set up a directory entry for .
*/

if(RVal == 0){
    MakDotDir(&DirEntry, pd);                                    /* pg. 546 */
    RVal = MakDirBlanks(&DirEntry, 1, pd,                         /* pg. 546 */
            &RegsCopy, procd, SysGlobs);
}

/*
    Patch the . directory into a .. entry
*/

if(RVal == 0){
    DirEntry.FileName[1] = '.';
    change_sex_2ia(DirEntry.StartCluster, pd→PD_Parent);
    RVal = MakDirBlanks(&DirEntry, 1, pd,                         /* pg. 546 */
            &RegsCopy, procd, SysGlobs);
}
```

```
    /*
        *Fill the rest of the directory with empty entries
    */

    if(RVal == 0){
        for(ptr=(uchar*)&DirEntry, i=sizeof(DirEntry); i>0; i––)
            *ptr++ = '\0';

        RVal = MakDirBlanks(&DirEntry,                              /* pg. 546 */
                (int)(INIT_DIR_SIZE(pd)*(SECTORSIZE/sizeof(DirEntry))–2),
                pd, &RegsCopy, procd, SysGlobs);

        DirSetFileLength(pd, 0L);     /*all directories show zero length */   /* pg. 559 */
    }

    Close(pd, regs, procd, SysGlobs);                              /* pg. 547 */
    return RVal;
}


MakDirBlanks(MSDirE DirEntry, int n, PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    int RVal;
    u_char *ptr;
    int16 i;

    regs→R_a0 = (char *)DirEntry;
    regs→R_d1 = sizeof(*DirEntry);

    for(RVal = 0; n >0; n––)
        if((RVal = Write(pd, regs, procd, SysGlobs)) != 0)          /* pg. 533 */
            break;
    return RVal;
}


void MakDotDir(MSDirE DirEntry, PD_TYPE pd)
{
    register uchar *ptr;
    register short i;

    for(ptr = (uchar *)DirEntry, i = sizeof(*DirEntry); i >0; i––)
        *ptr++ = '\0';
    DirEntry→FileName[0] = '.';
    for(i=1;i<8; ++i)
        DirEntry→FileName[i] = ' ';
    for(i=0;i<3; ++i)
        DirEntry→FileExtension[i] = ' ';

    DirEntry→FileAttr = MS_SUBDIR;
    change_sex_2ia(DirEntry→StartCluster,pd→PD_FCluster);                    /* pg. 561 */
}
```

C.2.8 Close.c

The Close() function has two roles:

- It writes dirty cached data to the disk (the file descriptor image and the FAT).
- It frees the memory InitPD() allocated for the path.

```
#include <procid.h>
typedef char *POINTER;
#include "format.h"
#include "PathDesc.h"

int Close(PD_TYPE pd, REGS regs, void *procd, void *SysGlobs)
{
    DriveTableType *DriveTable;

    DriveTable = pd→PD_DTB;

    if(pd→PD_SMF & PD_DIRTYFD)
        UpdateFD(pd, regs, procd, SysGlobs);                                  /* pg. 558 */

    if(DriveTable→V_FATDirty)
        WriteFAT(pd, regs, procd, SysGlobs);                                  /* pg. 580 */

    if(pd→PD_CNT == 0){            /*Is anyone still using this path? */
        if(pd→PD_BUF != 0)           /*Is there a buffer for this path? */
            DoSRtMem(pd→PD_BUF, SECTORSIZE);          /*Free it */        /* pg. 526 */
        pd→PD_BUF = NULL;

        if(pd→PD_FDBUF != 0)           /*Is there an FD buffer for this path? */
            DoSRtMem(pd→PD_FDBUF, SECTORSIZE);          /*Free it */
        pd→PD_FDBUF = NULL;
        FreeFAT(DriveTable);                                                  /* pg. 581 */
```

[†] *close*: see page 377

```
    }

    return 0;
}
```

C.2.9 Delete.c

Delete opens the file to ensure that it exists, the caller has write access to it, and so forth. The open also saves the location of the directory entry in the path descriptor. The actual deletion is done by the Close( ) function. Delete( ) primes the path descriptor by giving the file a zero length, freeing FAT entries as required, and changing the file name to ERASED in the path descriptor.

```
#include <procid.h>

typedef void *POINTER;
#include "format.h"
#include "PathDesc.h"

int Delete(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    int RVal;

    /*
        It would be consistant with OS-9 policy to refuse to delete a directory
        file.
    */
    /*Open the file for read */
    if((RVal = Open(pd, regs, procd, SysGlobs)) != 0)                 /* pg. 539 */
        return RVal;

    /*Shorten the file to zero */
    FATSetFileLength(pd, 0L);         /*free the entire file */       /* pg. 576 */

    /*
        Write a $E5 into the first byte of the file name in the directory. This
        signifies that the file has been erased.
    */
    *(pd→PD_Name) = FILERASED;
    DIRTYFD(pd);
    Close(pd, regs, procd, SysGlobs);                                 /* pg. 547 */
    return 0;
}
```

[†] *delete*: see page 378

C.2.10 Msfm.c

Most of the functions in this file are "easy." Seek() is certainly the simplest function this file manager implements. It is supposed to update the current position in the file. It does that—in one statement—and returns.

The ChgDir() function finds the requested directory and saves information in the process descriptor. FindFile() can use the the data saved by ChgDir() to find the default directories on the disk. IOMan has already taken care of saving the default *device*.

```
#include <errno.h>
#include <procid.h>
#include <modes.h>
#include <sg_codes.h>
#include <direct.h>

typedef char *POINTER;

#include "format.h"
#include "PathDesc.h"

static int WriteFD(PD_TYPE, struct fildes *, u_int16);


int ChgDir(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    int RVal;
    DefaultDescriptor *dptr;

    regs→R_d0 |= S_IFDIR;          /*Call for directory mode */
    if((RVal = Open(pd, regs, procd, SysGlobs)) != 0)                  /* pg. 539 */
        return RVal;

    dptr = (DefaultDescriptor *)procd→_dio;
    if(regs→R_d0 & S_IEXEC)
        ++dptr;

    dptr→DirCluster = pd→PD_FCluster;

    Close(pd, regs, procd, SysGlobs);                                  /* pg. 547 */
```

†*seek*: see page 375

```
    return 0;
}


int Seek(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    pd→PD_CP = regs→R_d1;
    return 0;
}


int GetStat(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    short limit;
    int RVal;

    switch((ushort)regs→R_d1){
        case SS_Size:
                regs→R_d2 = pd→PD_SIZ;
                break;
        case SS_Pos:
                regs→R_d2 = pd→PD_CP;
                break;
        case SS_EOF:
                if(pd→PD_CP >= pd→PD_SIZ)
                    return E_EOF;
                else
                    regs→R_d1 = 0;
                break;
        case SS_FDInf:
                if((RVal = GetFD(pd, regs, procd, SysGlobs, regs→R_d3)) != 0)     /* pg. 567 */
                    return RVal;
                /*Drop through */
        case SS_FD:
                limit = regs→R_d2;
                if(limit > 256)
                    return E_UNKSVC;
                MoveData(regs→R_a0, &(pd→PD_FD), limit);                           /* pg. 527 */
                break;
        case SS_Opt:
                break;
        case SS_DevNm:
                break;
        default:
                return DriverGetStat(pd, regs, procd, SysGlobs);                   /* pg. 552 */
    }
    return 0;
}


SetStat(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    int RVal;
    REGISTERS CopyRegs;

    switch((ushort)regs→R_d1){
        case SS_Size:
                return SetFileSize(pd, regs→R_d2);                  /* pg. 535 */
        case SS_FD:         /* Write FD sector */
                return WriteFD(pd, (struct fildes *)regs→R_a0,       /* pg. 551 */
                        procd→_user);
        case SS_Attr:       /* Set the file attributes */
                DirSetFileAttr(pd, regs→R_d2);                       /* pg. 559 */
                break;
        case SS_Opt:        /* This is ioman's business */
                break;
        case SS_Reset:
        case SS_WTrk:       /* Not supported here. Pass itto the device driver */
        default:
                return DriverSetStat(pd, regs, procd, SysGlobs);    /* pg. 551 */
    }
    return 0;
}


static int WriteFD(PD_TYPE pd, struct fildes *fd, u_int16 User)
{
    if(pd→PD_Accs & S_IWRITE){
        DirSetFileDate(pd, fd→fd_date);                              /* pg. 558 */
        DirSetCrDate(pd, fd→fd_dcr);                                 /* pg. 558 */
        if(User == 0)
            DirSetFileOwner(pd, *(ushort *)(fd→fd_own));             /* pg. 558 */
        return 0;
    }else
        return E_BMODE;
}


int DriverSetStat(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    int RVal;
    register STATICSTORETYPE DevStatic;

    DevStatic = pd→PD_DEV→V_STAT;

    /* Wait for the device to be idle */
    while(DevStatic→V_BUSY) DoIOQ(DevStatic→V_BUSY);           /* pg. 526 */
    DevStatic→V_BUSY = pd→PD_CPR;

    RVal = CallSetStat(regs→R_d1, pd, pd→PD_DEV→V_STAT,        /* pg. 525 */
    procd, regs, SysGlobs);

    DevStatic→V_BUSY = 0;            /*device not busy */

    return RVal;
}


int DriverGetStat(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    int RVal;
    STATICSTORETYPE DevStatic;

    DevStatic = pd→PD_DEV→V_STAT;

    /* Wait for the device to be idle */
    while(DevStatic→V_BUSY) DoIOQ(DevStatic→V_BUSY);           /* pg. 526 */
    DevStatic→V_BUSY = pd→PD_CPR;

    RVal = CallGetStat(regs→R_d1, pd, pd→PD_DEV→V_STAT,        /* pg. 524 */
            procd, regs, SysGlobs);

    DevStatic→V_BUSY = 0;            /*device not busy */
    return RVal;
}
```

C.3 Service Functions

The service functions are called by the main functions. They are distinguished by the files into which they are grouped. Some service functions share a file with one of the file manager's main entry points. These service functions are shared by several of the main functions.

C.3.1 Dir

The functions in the file, dir.c, manipulate directory files. There are functions here that search a directory for a given file name or an empty entry. Other functions update the virtual file descriptor in the path descriptor and update the directory entry on disk.

A large part of the action of FindFile is encapsulated in DirEntryFound(). This function applies information from (and about) a directory entry to the path descriptor.

MakDirEntry() handles most of the work for Create().

```
#include <errno.h>
#include <procid.h>
#include <modes.h>
#include <direct.h>
typedef char *POINTER;
#include "format.h"
#include "PathDesc.h"

/*
    Prototypes
*/
int DirEntryFound(PD_TYPE, struct dirent *, procid *);
int ReadEntry(struct dirent *, PD_TYPE, procid *, void *);


#define HUGE                    0xffffffff; /*BIG number ... unsigned */

DirLookup(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    struct dirent DirEntry;
    int RVal;

    if(pd→PD_SMF & PD_RAWMODE){
        pd→PD_SIZ = HUGE;
        return(0);
    }

    pd→PD_Parent = pd→PD_FCluster;

    /*
        A special case: If the current directory is the root directory, the parent
        is also the root directory even though no parent is given in the directory
        structure.
    */
```

[†] *makdirentry*: see page 557

```
    if(pd→PD_SMF & PD_RDIR_MODE)
        if((NameMatch((u_char *)".", pd→PD_Name) == 0) ||                  /* pg. 554 */
                (NameMatch((u_char *)"..", pd→PD_Name) == 0)){
            SetRootDir(pd, procd, PATHDELIM);                               /* pg. 555 */
            pd→PD_CP = 0;
            return 0;
        }

    while(ReadEntry(&DirEntry, pd, procd, SysGlobs) == 0)                   /* pg. 556 */
        if(NameMatch((u_char *)DirEntry.dir_name, pd→PD_Name) == 0){        /* pg. 554 */
            if((RVal = GetFD(pd, regs, procd,                               /* pg. 567 */
                    SysGlobs, DirEntry.dir_addr)) != 0)
                return RVal;
            return DirEntryFound(pd, &DirEntry, procd);                     /* pg. 554 */
        }else if(DirEntry.dir_addr == 0) /*no further entries */
            break;

    return E_PNNF;
}


boolean NameMatch(u_char *Name1, u_char *Name2)
{
    /*empty name: match empty or erased */
    if((*Name2 == '\0') || (*Name2 == '\345'))
        if((*Name1 == '\0') || (*Name1 == '\345'))
            return 0;               /*a match */
        else
            return 1;               /*no match */

    return (ncstrcmp(Name1, Name2));                                        /* pg. 560 */
}


int DirEntryFound(PD_TYPE pd, struct dirent *DirEntry, procid *procd)
{
    pd→PD_FDSector = pd→PD_CSector;
    pd→PD_DCP = pd→PD_CP – sizeof(MSDirEntry);
    pd→PD_FDOffset = FDOFFSET(DirEntry→dir_addr);
    pd→PD_ATT = pd→PD_FD.vfd_att;
    pd→PD_FCluster = array_to_int(pd→PD_FD.vfd_cluster,2);
    pd→PD_SIZ = array_to_int(pd→PD_FD.vfd_fsize, 4);
    pd→PD_CP = 0;
    if(pd→PD_ATT & S_IFDIR){/*a directory */
        pd→PD_SMF |= PD_DIR_MODE;
        if(pd→PD_FCluster == 0)
            SetRootDir(pd, procd, PATHDELIM);                                /* pg. 555 */
        else{
            pd→PD_SMF &=  PD_RDIR_MODE;
            pd→PD_SIZ = HUGE;
        }
    }else
        pd→PD_SMF &=  (PD_DIR_MODE | PD_RDIR_MODE);
    return 0;
}


int AdjustAttributes(u_char msAttr)
{
    register int attr;

    attr = 0x03f;                   /*%00111111 RWErwe  */
    if(msAttr & 0x01)                    /*read only  */
        attr &= 0x2d;
    if(msAttr & 0x010)                   /*directory file  */
        attr |= 0x80;
    return attr;
}


u_char ReAdjustAttributes(u_char osAttr)
{
    register u_char attr;

    attr = 0;
    if(!(osAttr & 0x12))                 /*read only  */
        attr |= 0x01;
    if(osAttr & 0x80)                  /*directory  */
        attr |= 0x010;
    return attr;
}


/*
     Set up for reading the "root directory." If the path name begins with
    *a slash, the root directory is the disk's root directory. If the path name
     does not begin with a slash the root directory is a current directory.
*/
void SetRootDir(PD_TYPE pd, procid *procd, char Delim)
{
    pd→PD_SIZ = HUGE;
    if(Delim == PATHDELIM)
        pd→PD_SMF |= (PD_RDIR_MODE | PD_DIR_MODE);               /*Root Directory */
    else {
        register DefaultDescriptor *dptr;

        dptr = (DefaultDescriptor *)procd→_dio;
        if(pd→PD_Accs & S_IEXEC)
            ++dptr;
        if(dptr→DirCluster == 0)
            pd→PD_SMF |= (PD_RDIR_MODE | PD_DIR_MODE); /*Root Directory */
        else {
            pd→PD_FCluster = dptr→DirCluster;
            pd→PD_SMF |= PD_DIR_MODE;
        }
    }
    if(pd→PD_SMF & PD_RDIR_MODE)
        pd→PD_FCluster = 0; /*root directory */

    pd→PD_ATT = AdjustAttributes(MS_SUBDIR); /*directory */
    return;
}


int ReadEntry(struct dirent *Entry, PD_TYPE pd, procid *procd, void *SysGlobs)
{
    REGISTERS regs;

    regs.R_d1 = sizeof(MSDirEntry);
    regs.R_a0 = (void *)Entry;

    return Read(pd, &regs, procd, SysGlobs);                      /* pg. 529 */
}


int FindEmpty(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    struct dirent DirEntry;

    pd→PD_CP = 0;
    pd→PD_SIZ = HUGE;               /*This must be a directory */
    pd→PD_SMF |= PD_DIR_MODE;

    while(ReadEntry(&DirEntry, pd, procd, SysGlobs) == 0)         /* pg. 556 */
        if(NameMatch((u_char *)DirEntry.dir_name, (u_char *)"") == 0)  /* pg. 554 */
```

```
            return 0;
    return E_PNNF;
}


int MakDirEntry(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    int RVal;
    char Date[5];
    MSDirEntry DirEntry;
    int16 Offset;


    /*get an empty directory entry */
    if((RVal = FindEmpty(pd, regs, procd, SysGlobs)) != 0){          /* pg. 556 */
        /*did not find an empty spot */
        /*try extending the directory file */
        SYSDEBUG(5, pd);
        return RVal;
    }
    DirSetFileLength(pd, 0);                                          /* pg. 559 */
    DirSetFileOwner(pd, 0);                                           /* pg. 558 */
    DirSetFileLink(pd, 1);                                            /* pg. 558 */
    DirSetFileAttr(pd, (ushort)regs->R_d1);                           /* pg. 559 */
    GetDate(Date);                                                    /* pg. 526 */
    DirSetFileDate(pd, Date);                                         /* pg. 558 */
    DirSetCrDate(pd, Date);                                           /* pg. 558 */
    DirSetFCluster(pd, FAT_LASTSECTOR);                               /* pg. 558 */
    UpdateDirEntFromPD(&DirEntry, pd);                                /* pg. 569 */
    Offset = ((pd->PD_SMF & PD_RDIR_MODE) ?
            (pd->PD_CP / sizeof(DirEntry) – 3):
            (pd->PD_CP / sizeof(DirEntry) – 1)) &
            ((SECTORSIZE / sizeof(DirEntry)) – 1);
    if((RVal = WriteDirEntry(&DirEntry, pd->PD_CSector, Offset,       /* pg. 559 */
            pd, regs, procd, SysGlobs)) != 0)
        return RVal;
    /*Set up the path descriptor for the new file */
    pd->PD_SMF = pd->PD_CP = pd->PD_SIZ = 0;
    pd->PD_FCluster = FAT_LASTSECTOR;
    pd->PD_FDOffset = Offset;
    pd->PD_FDSector = pd->PD_CSector;
    pd->PD_Accs = regs->R_d0;
    return 0;
}
```

```
int UpdateFD(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    char Date[5];
    MSDirEntry DirEntry;


#ifdef ALWAYS_STAMP
    GetDate(Date);                                               /* pg. 526 */
    DirSetFileDate(pd, Date);                                    /* pg. 558 */
#endif /*ALWAYS_STAMP */
    UpdateDirEntFromPD(&DirEntry, pd);                           /* pg. 569 */
    CLEANFD(pd);

    return (WriteDirEntry(&DirEntry, pd→PD_FDSector, pd→PD_FDOffset, /* pg. 559 */
            pd, regs, procd, SysGlobs));
}


void DirSetFileOwner(PD_TYPE pd, int owner)
{
    int_to_array(pd→PD_FD.vfd_own, owner, 2);
}

void DirSetFileLink(PD_TYPE pd, int link)
{
    pd→PD_FD.vfd_link = link;
}


void DirSetFileDate(PD_TYPE pd, char Date[5])
{
    (void)MoveData(pd→PD_FD.vfd_date, Date, 5);                  /* pg. 527 */
}


void DirSetCrDate(PD_TYPE pd, char Date[5])
{
    (void)MoveData(pd→PD_FD.vfd_dcr, Date, 3);                   /* pg. 527 */
}


void DirSetFCluster(PD_TYPE pd, u_int16 Cluster)
{
    int_to_array(pd→PD_FD.vfd_cluster, Cluster, 2);              /* pg. 561 */
}
```

```
void DirSetFileLength(PD_TYPE pd, u_int32 length)
{
    int_to_array(pd→PD_FD.vfd_fsize, length, 4);                    /* pg. 561 */
    pd→PD_SIZ = length;
    DIRTYFD(pd);
}


void DirSetFileAttr(PD_TYPE pd, u_int16 Attr)
{
    pd→PD_FD.vfd_att = Attr;
    pd→PD_ATT = Attr;
    DIRTYFD(pd);
}


int WriteDirEntry(MSDirE DirEntry, u_int32 Sector, int16 Offset,
PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    MSDirE DirPtr;
    int RVal;


    if(Sector < 5) SYSDEBUG(2, Sector);

    /* This sector may be in the buffer—translated */
    /* Get it again */
    if((RVal = RawReadSector(pd, Sector, pd→PD_BUF,                  /* pg. 562 */
            regs, procd, SysGlobs)) != 0){
        SYSDEBUG(Sector, pd);          /* bad trouble */
        return(RVal);
    }


    DirPtr = ((MSDirE)pd→PD_BUF) + Offset;
    *DirPtr = *DirEntry;


    if((RVal = RawWriteSector(pd, Sector, pd→PD_BUF, regs,           /* pg. 563 */
            procd, SysGlobs)) != 0){
        SYSDEBUG(Sector, pd);          /* bad trouble */
        return RVal;
    }
    return 0;
}
```

C.3.2 Utils

```
#include <procid.h>
typedef void *POINTER;
#include "format.h"
#include "PathDesc.h"

int strncmp(u_char *s1, u_char *s2, u_int32 n)
{
    for(; n> 0; n−−)
        if(*s1++ != *s2++) return (*(s1−1) − *(s2−1));
    return 0;
}


int ncstrcmp(u_char *s1, u_char *s2)
{
    while(*s2)
        if(toupper(*s1++) != toupper(*s2++))                    /* pg. 560 */
            return(*(s1−1) − *(s2−1));
    return(*s1);
}


char toupper(char c)
{
    c &= 0x7F;
    return (((c >= 'a') && (c <= 'z')) ? (c & 0x005f) : c);
}



boolean islegal(char c)
{
    return (((c >= 'a') && (c <= 'z')) ||
            ((c >= 'A') && (c <= 'Z')) ||
            ((c >= '0') && (c <= '9')) ||
            (c == '_') || (c == '-') || (c == '$'));
}


u_int32 u_bound_div(u_int32 a, int32 b)
{
    return ((a+b−1)/b);
}
```

```
int array_to_int(u_char *a, u_int16 l)
{
    int acc;

    for(acc=0;l > 0;--l)
        acc = (acc << 8) + *a++;
    return acc;
}


void int_to_array(u_char *a, int i, int len)
{
    register unsigned char *ptr;

    ptr = (unsigned char *)&i;
    len = sizeof(int) - len;
    for(;len < sizeof(int);++len)
        *a++ = ptr[len];
}


void change_sex_2ia(u_char *a, int b)
{
    a[0]= (unsigned char)b;
    a[1]= (unsigned char)(b >> 8);
}
```

C.3.3 ReadSector

This file contains the low-level interface to the device driver's read-sector entry. ReadSector contains part of the code that makes PC-Dos directories look like OS-9 directories. Note that RawReadSector() is careful to mark sectors that haven't been through the PC-Dos to OS-9 mapping not-good. This prevents raw PC-Dos directories from being cached and used as if they had been mapped.

The loop that calls DoIOQ() before the read is important. This is where paths queue up for access to a device.

```
#include <errno.h>
#include <procid.h>
typedef char *POINTER;
#include "format.h"
#include "PathDesc.h"
```

```
int RawReadSector(PD_TYPE pd, u_int32 Sector, char *buffer, REGS regs,
        procid * procd, void *SysGlobs)
{
    uchar HoldSMF;
    int RVal;

    HoldSMF = pd→PD_SMF;
    pd→PD_SMF = PD_RAWMODE;
    RVal= ReadSector(pd, Sector, buffer, regs, procd, SysGlobs);                    /* pg. 562 */
    pd→PD_SMF = HoldSMF &  PD_GOODBUF;
    return RVal;
}


int ReadSector(PD_TYPE pd, u_int32 Sector, char *buffer,
REGS regs, procid *procd, void *SysGlobs)
{
    int ReturnVal;
    char *HoldBuffer;
    register STATICSTORETYPE DevStatic;

    if((Sector == pd→PD_CSector) && (pd→PD_SMF & PD_GOODBUF))
        return 0;

    DevStatic = pd→PD_DEV→V_STAT;

    /* Wait for the device to be idle  */
    while(DevStatic→V_BUSY) DoIOQ(DevStatic→V_BUSY);                               /* pg. 526 */
    DevStatic→V_BUSY = pd→PD_CPR;

    /* The supplied buffer might not be the one in the path descriptor  */
    HoldBuffer = pd→PD_BUF;
    pd→PD_BUF = buffer;

    /* Call the device driver to read a sector  */
    ReturnVal = CallRead(1 /*contig sectors  */,                                   /* pg. 523 */
            Sector /*sector number  */,
            pd,
            DevStatic, /*device static storage  */
            procd,
            regs,
            SysGlobs);

    DevStatic→V_BUSY = 0; /*device not busy  */
    pd→PD_BUF = HoldBuffer;

    /*Deal with a strangeness of the driver */
    if((Sector == 0) && (ReturnVal == E_BTYP))
        ReturnVal = 0;

    if((Sector == 0) && (ReturnVal == 0 ))
        InitFromBoot(pd, (BootSectorType)pd→PD_BUF, regs, procd, SysGlobs);/* pg. 566 */

    /*Update the Current Sector field in the path descriptor */
    if(ReturnVal == 0){
        pd→PD_CSector = Sector;
        pd→PD_SMF |= PD_GOODBUF;
        if((pd→PD_SMF & PD_DIR_MODE) && !(pd→PD_SMF & PD_RAWMODE))
            SectorMs2os9(pd, (MSDirE)buffer);                          /* pg. 568 */
    }else
        pd→PD_SMF &=  PD_GOODBUF;

    return ReturnVal;
}
```

C.3.4 WriteSector

WriteSector( ) implements the low-level interface to the device driver's write-sector entry.

The RawwriteSector( ) function pretends that some writes might pass through a OS-9 to PC-Dos mapping. They don't. Data must be mapped before it is passed to WriteSector( ).[2]

```
#include <errno.h>
#include <procid.h>
typedef char *POINTER;
#include "format.h"
#include "PathDesc.h"

int RawWriteSector(PD_TYPE pd, u_int32 Sector, char *buffer, REGS regs,
procid *procd, void *SysGlobs)
{
    uchar HoldSMF;
    int RVal;

    HoldSMF = pd→PD_SMF;
```

[2]The Write( ) function does mapping as required.

```
    pd→PD_SMF = PD_RAWMODE;
    RVal= WriteSector(pd, Sector, buffer, regs, procd, SysGlobs);          /* pg. 564 */
    pd→PD_SMF = HoldSMF;
    return RVal;
}


int WriteSector(PD_TYPE pd, u_int32 Sector, char *buffer, REGS regs,
procid *procd, void *SysGlobs)
{
    int ReturnVal;
    char *HoldBuffer;
    STATICSTORETYPE DevStatic;

    DevStatic = pd→PD_DEV→V_STAT;
    #ifndef FINAL
    if(Sector == 0) /*we shouldn't be doing this */
        return 99;
    #endif

    /*Wait for the device to be idle */
    while(DevStatic→V_BUSY) DoIOQ(DevStatic→V_BUSY);                      /* pg. 526 */
    DevStatic→V_BUSY = pd→PD_CPR;

    /*The supplied buffer might not be the one in the path descriptor */
    HoldBuffer = pd→PD_BUF;
    pd→PD_BUF = buffer;

    /*Call the device driver to write a sector */
    ReturnVal = CallWrite(1 /*contig sectors */,                           /* pg. 524 */
            Sector /*sector number */,
            pd,
            DevStatic, /*device static storage */
            procd,
            regs,
            SysGlobs);

    DevStatic→V_BUSY = 0; /*device not busy */

    pd→PD_BUF = HoldBuffer;

    /*Update the Current Sector field in the path descriptor */
    if(ReturnVal == 0)
        pd→PD_CSector = Sector;
    return ReturnVal;
```

```
}
```

C.4 Artifacts of PC-DOS

A file manager contains knowledge about the file system it implements. The functions in this section do most of the PC-Dos-specific operations. This is not the place to learn about PC-Dos. I recommend the Norton book *Programmer's Guide to the IBM PC.* I used it to write this driver.

One adjustment from the PC-Dos file structure is repeated often. The Intel 80x8x line of processors uses a different byte ordering from the Motorola 680xx line. These functions convert integers between formats.

C.4.1 Drivetable.c

The device driver updates the drive table whenever the driver is asked to read sector zero. It updates the drive table by copying the beginning of sector zero into the table. Since the beginning of the PC-Dos boot sector is nothing like an OS-9 disk ID sector, the file manager has to rework what the driver did.

This file contains functions that inspect the PC-Dos boot sector and the beginning of the FAT, and generate a drive table entry from that information.

```
#include <errno.h>
#include <procid.h>
typedef char *POINTER;
#include "format.h"
#include "PathDesc.h"
static InitDriveTable(PD_TYPE, u_int16, u_int16, u_int32, u_int32,
        u_int32, u_int32, u_int16, u_int32);

static InitDriveTable(PD_TYPE pd, u_int16 FATStart, u_int16 FATCopies,
        u_int32 DirSize, u_int32 ClusterSize,
        u_int32 FATSize, u_int32 TrackSize, u_int16 Sides,
        u_int32 Size)
{
    register DriveTableType *DriveTable;

    DriveTable = (DriveTableType *)pd->PD_DTB;
    int_to_array((u_char *)DriveTable->DD_TOT, Size, 3);
    DriveTable->DD_TKS = TrackSize & 0x00ff;
    int_to_array((u_char *)DriveTable->DD_SPT, TrackSize, 2);
    pd->PD_TOS = TrackSize;          /*Sectors in track 0 is the same as Tracksize */
    DriveTable->DD_FMT =
            ((Sides == 2) ? 1 : 0) +          /*1: double sided */
            2 +           /*2: always double density */
            ((Size > 720) ? 4 : 0);           /*4: 80 track */
    DriveTable→V_FATSz = FATSize;
    DriveTable→DD_DIR = FATStart + (FATSize * FATCopies);
    DriveTable→DD_FirstFAT = FATStart;
    DriveTable→DD_FATCnt = FATCopies;
    DriveTable→V_DirEntries = DirSize;
    DriveTable→DD_FATSIZ = FATSize;
    DriveTable→DD_SPC = ClusterSize;
    /*
        The first sector of data is after the boot (1 sector), the FAT, and
        the directory.
    */
    DriveTable→V_DataStart = (FATSize * FATCopies) + (DirSize/16) − 2;
}


void InitFromBoot(PD_TYPE pd, BootSectorType BootPtr, REGS regs,
        procid *procd, void *SysGlobs)
{
    char *ptr;
    uchar id;
    int RVal;

    if((ptr = (char *)_srqmem(SECTORSIZE)) == (char *)−1){                /* pg. 525 */
        SysDebug(E_MEMFUL, pd);
        id = 0x0FD;           /*desperate attempt */
    }else {
        uchar hold_vinit = pd→PD_DTB→V_Init;
        pd→PD_DTB→V_Init = 1;
        if((RVal = RawReadSector(pd, 1L, ptr, regs, procd, SysGlobs)) != 0){   /* pg. 562 */
            SYSDEBUG(RVal, pd);           /*nothing's supposed to go wrong */
            id = 0x0FD;
        }else
            id = *ptr;
        DoSRtMem(ptr, pd→PD_SSize);                                       /* pg. 526 */
        pd→PD_DTB→V_Init = hold_vinit;
    }

    switch(id){
        case 0xff:          /*double sided 8 sector */
                InitDriveTable(pd, 2, 2, 112, 2, 1, 8, 2, 640);           /* pg. 565 */
                break;
        case 0xfe:          /*single sided 8 sector */
```

```
                InitDriveTable(pd, 2, 2, 64, 1, 1, 8, 1, 320);                    /* pg. 565 */
                break;
        case 0xf0:          /*double-sided 18 sector */
                InitDriveTable(pd, 2, 2, 224, 1, 9, 18, 2, 1440);                  /* pg. 565 */
                break;
        default:
                InitDriveTable(pd,                                                 /* pg. 565 */
                        2,          /*Start of FAT */
                        BootPtr→FATCopies,
                        (BootPtr→RootDirSize[1] << 8) + BootPtr→RootDirSize[0],
                        BootPtr→SectorsPerCluster,
                        (BootPtr→SectorsPerFAT[1] << 8) + BootPtr→SectorsPerFAT[0],
                        (BootPtr→SectorsPerTrack[1] << 8) + BootPtr→SectorsPerTrack[0],
                        (BootPtr→Sides[1] << 8) + BootPtr→Sides[0],
                        (BootPtr→TotSectors[1] << 8) + BootPtr→TotSectors[0]);
                break;
    }
}
```

C.4.2 GetFD.c

PC-Dos doesn't use file descriptors as such, but OS-9 insists on them. This file manager creates a virtual file descriptor whenever a file is opened. The GetFD() function builds the virtual file descriptor for the path.

```
#include <errno.h>
#include <procid.h>
typedef char *POINTER;
#include "format.h"
#include "PathDesc.h"

int GetFD(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs, u_int32 fdcode)
{
    int RVal;

    if(pd→PD_FDHash == fdcode)
        return 0;
    else
        if((RVal = RawReadSector(pd, (ulong)(fdcode >> 4),                        /* pg. 562 */
                (char *)pd→PD_FDBUF, regs,
                procd, SysGlobs)) != 0)
            return RVal;

    Dir2FD(&pd→PD_FD, ((MSDirE)pd→PD_FDBUF) + (fdcode & 0x0f));  /* pg. 568 */
    pd→PD_FDHash = fdcode;
    return 0;
}
```

C.4.3 TransDir

TransDir( ) converts PC-Dos directory entries into OS-9 directory entries, and merges OS-9 directory entries with virtual file descriptors to make PC-Dos directory entries.

```
/*#include <ctype.h> */
#include <errno.h>
#include <procid.h>
#include <direct.h>
typedef char *POINTER;
#include "format.h"
#include "PathDesc.h"

static void ms2os9(MSDirE, struct dirent *, u_int32, u_int32);
static void OS9DirE2MS(struct dirent *, MSDirE, MSDirE);

void SectorMs2os9(PD_TYPE pd, MSDirE buffer)
{
    register int i;

    for(i=0; i< (SECTORSIZE/sizeof(struct dirent)); ++i, ++buffer){
        pd→PD_FDBUF[i] = *buffer;
        ms2os9(buffer, (struct dirent *)buffer, pd→PD_CSector, i);          /* pg. 570 */
    }
}


void Dir2FD(VirFDPtr fd, MSDirE msdir) /* This can be done in place */
{
    unsigned short DateNum, TimeNum;

    fd→vfd_att = AdjustAttributes(msdir→FileAttr);                          /* pg. 555 */
    fd→vfd_own[0] = 0;
    fd→vfd_own[1] = 0;
    DateNum = (uchar)msdir→Date[0] + (256 * (uchar)msdir→Date[1]);
    TimeNum = (uchar)msdir→Time[0] + (256 * (uchar)msdir→Time[1]);
    fd→vfd_dcr[0] = fd→vfd_date[0] = (DateNum >> 9) + 80;
    fd→vfd_dcr[1] = fd→vfd_date[1] = (DateNum >> 5) & 0x0f;
    fd→vfd_dcr[2] = fd→vfd_date[2] = DateNum & 0x01f;
    fd→vfd_date[3] = TimeNum >> 11;
    fd→vfd_date[4] = (TimeNum >> 5) & 0x03f;
    fd→vfd_link = 1;
    fd→vfd_fsize[0] = msdir→FileSize[3];
    fd→vfd_fsize[1] = msdir→FileSize[2];
    fd→vfd_fsize[2] = msdir→FileSize[1];
    fd→vfd_fsize[3] = msdir→FileSize[0];
    fd→vfd_cluster[0] = msdir→StartCluster[1];
    fd→vfd_cluster[1] = msdir→StartCluster[0];
    return;
}


void UpdateDirEntFromPD(MSDirE DirPtr, PD_TYPE pd)
{
    register uchar *from, *to;
    register int counter;

    /*Convert the file name from OS-9 format to MSDos format */
    for(from = pd→PD_Name, to = DirPtr→FileName, counter = 8;
            *from && (*from != '.'); counter––)
        *to++ = *from++;
    for(;counter >0; counter––) *to++ = ' ';
    if(*from == '.')
        ++from;
    for(counter = 3, to = DirPtr→FileExtension; *from > ' '; counter––)
        *to++ = *from++;
    for(;counter >0; counter––) *to++ = ' ';

    for(counter = 9; counter >=0; counter––)
        DirPtr→Reserved[counter] = '\0';

    DirPtr→FileAttr = ReAdjustAttributes(pd→PD_FD.vfd_att);

    DirPtr→Date[1] = (pd→PD_FD.vfd_date[0] − 80) * 2 +
            (pd→PD_FD.vfd_date[1] >> 3);
    DirPtr→Date[0] = (pd→PD_FD.vfd_date[1] & 0x07) * 32 +
            pd→PD_FD.vfd_date[2];
    DirPtr→Time[1] = (pd→PD_FD.vfd_date[3] * 8) /*hour */ +
            (pd→PD_FD.vfd_date[4] >> 3);
    DirPtr→Time[0] = (pd→PD_FD.vfd_date[4] & 0x07) << 5;

    DirPtr→StartCluster[0] = pd→PD_FD.vfd_cluster[1];
    DirPtr→StartCluster[1] = pd→PD_FD.vfd_cluster[0];

    DirPtr→FileSize[0] = pd→PD_FD.vfd_fsize [3];
    DirPtr→FileSize[1] = pd→PD_FD.vfd_fsize [2];
    DirPtr→FileSize[2] = pd→PD_FD.vfd_fsize [1];
    DirPtr→FileSize[3] = pd→PD_FD.vfd_fsize [0];
    return;
}
```

```
static void ms2os9(MSDirE msdir, struct dirent *osdir, u_int32 csector, u_int32 coffset)
{
    register uchar *ptr1, *ptr2;
    register short i;
    struct dirent work;

    for(i=0; i < 28; ++i)
            work.dir_name[i] = '\0';
    for(i=0, ptr1 = (uchar *)work.dir_name, ptr2 = msdir→FileName;
            (i < 8) && (*ptr2 > ' ') && (*ptr2 < 0x080); ++i)
        *ptr1++ = *ptr2++;
    if((msdir→FileExtension[0] > ' ') && (i > 0)){
        *ptr1++ = '.';
        for(i=0, ptr2 = msdir→FileExtension; (i < 3) && (*ptr2 > ' '); ++i)
            *ptr1++ = *ptr2++;
    }

    if(msdir→FileName[0] == '\0')
        work.dir_addr = 0;
    else
        /*
            Make a fake fd sector address out of the sector # and position
            of the directory entry.
            Sector number is SSSSSSSS.
            CP is PPPPPPPP.
            fake fd is SSSSSSSP
            high-order 7 nybles of S and
            the bits from P picked out with ones: 000...00000111100000
        */
        work.dir_addr = MAKE_FD_HASH(csector,coffset);
    *osdir = work;
}
```

```
u_int32 FakeRootDir(u_int32 cp, u_int16 *Length, char **ptr)
{
    for(;(cp < (2 * sizeof(MSDirEntry))) && (*Length >0);
            ++cp, (*Length)––)
        if(cp == 0)
            *((*ptr)++) = ’.’;
        else if((cp == sizeof(MSDirEntry) –1) ||
                (cp == (2*sizeof(MSDirEntry)) –1))
            *((*ptr)++) = 1;
        else if(cp < sizeof(MSDirEntry))
            *((*ptr)++) = ’\0’;
        else if(cp < (sizeof(MSDirEntry) + 2))
            *((*ptr)++) = ’.’;
        else
            *((*ptr)++) = ’\0’;
    return cp;
}


int WriteIntoDir(int32 offset, int32 length, char *to, char *from)
{
    short int diroffset;

    for(;length >0; length –=sizeof(struct dirent),
            offset += sizeof(struct dirent)){
        diroffset = offset % sizeof(struct dirent);
        if(diroffset == 0){
            OS9DirE2MS((struct dirent *)from,                /* pg. 571 */
                    (MSDirE)to,
                    (MSDirE)to);
            from += sizeof(struct dirent);
            to += sizeof(MSDirEntry);
        }else if(offset < 12)
            return –1;              /*error */
        else return 0;              /*do nothing */
    }
    return 0;
}


static void OS9DirE2MS(struct dirent *os9, MSDirE ms, MSDirE oldms)
{
    uchar *ptr1, *ptr2;
    int i;
    *ms = *oldms;

    for(i=0, ptr2 = (uchar *)os9->dir_name, ptr1 = ms->FileName;i < 8;++i)
        if(*ptr2 && (*ptr2 != '.'))
            *ptr1++ = *ptr2++ & 0x7f;
        else
            *ptr1++ = ' ';
    if(*ptr2 == '.') ++ptr2;
    for(i=0; i < 3; ++i)
        if(*ptr2)
            *ptr1++ = *ptr2++;
        else
            *ptr1++ = ' ';
    return;
}
```

C.4.4 FATSupport

The File Allocation Table (FAT) stored on each PC-Dos disk is used to store links between sectors. Free sectors have a distinguished link number. Other link values indicate errors or point to other links. Each link corresponds to the equivalent of an OS-9 cluster.

```
#include <errno.h>
#include <procid.h>
typedef char *POINTER;
#include "format.h"
#include "PathDesc.h"

#define DIRTYFAT(DriveTable) (DriveTable)->V_FATDirty = TRUE
#define CLEANFAT(DriveTable) (DriveTable)->V_FATDirty = FALSE
#define SECTORS_ON_DEVICE(pd)        ((((pd->PD_DTB->DD_TOT[0]<<8)+\
                                     pd->PD_DTB->DD_TOT[1]<<8)+\
                                     pd->PD_DTB->DD_TOT[2])
static int ChaseFat(u_char *, u_int32, u_int32);
static int ChaseToEnd(u_char *, u_int32, u_int32 *);
static int FindFreeSector(u_char *, u_int16);
static int GetFreeSector(PD_TYPE);
static int ExtendFile(PD_TYPE, u_int16);
static void FreeFrom(u_int16 *, u_int16);
static u_int16 FAT(u_int16, u_char *);
static void SetFAT(u_char *, u_int16, u_int16);
static int FillFAT(PD_TYPE, REGS, procid *, void *);
```

```
int Errno(u_int32 FATCode)
{
    switch(FATCode){
        case T_FAT_BADTRACK:
            return E_DAMAGE;
        case T_FAT_LASTSECTOR:
            return E_EOF;
        default:
            if(FATCode >= T_FAT_BADTRACK)
                return E_DAMAGE;
            else
                return 0; /*no trouble  */
    }
}


/*
    Take the file relative location and convert it into a disk-relative sector
    number.
*/

static int ChaseFat(u_char *FATPtr, u_int32 FCluster, u_int32 ThisCluster)
{
    register ushort CNumber;

    if(FCluster == FAT_LASTSECTOR)
        return FCluster;

    for(CNumber = FCluster ; ThisCluster > 0; ThisCluster--)
        switch(CNumber = FAT(CNumber, FATPtr)){                    /* pg. 576 */
            case FAT_BADTRACK:
                return CNumber;
                break;
            case FAT_LASTSECTOR:
                return CNumber;
                break;
            default:
                break;
        }
    return CNumber;
}


/*
    Return the last cluster number for a file and the number of clusters in
    the file.
```

```
*/

static int ChaseToEnd(u_char *FATPtr, u_int32 FCluster, u_int32 *Count)
{
    u_int16 This;

    This = FCluster;
    *Count = 0;

    if((This == FAT_LASTSECTOR) || (This == 0))
        return FAT_LASTSECTOR;

    for(*Count = 1; (FCluster = FAT(This, FATPtr)) != FAT_LASTSECTOR;
            ++(*Count))
        This = FCluster;

    return This;
}


static int FindFreeSector(u_char *FATPtr, u_int16 HiFAT)
{
    register ushort num;

    for(num = 2; num < HiFAT; ++num)
        if(FAT(num, FATPtr) == 0)                              /* pg. 576 */
            break;

    if(num < HiFAT)
        return num;
    else
        return FAT_LASTSECTOR;
}


static int GetFreeSector(PD_TYPE pd)
{
    register ushort num;

    DIRTYFAT(pd→PD_DTB);

    if((num = FindFreeSector((uchar *)pd→PD_DTB→V_FATPtr,      /* pg. 574 */
            (short)((SECTORS_ON_DEVICE(pd) – pd→PD_DTB→V_DataStart) /
            pd→PD_DTB→DD_SPC) + 1))) < FAT_BADTRACK)
        SetFAT((uchar *)pd→PD_DTB→V_FATPtr, num, FAT_LASTSECTOR);/* pg. 577 */
    return num;
}


static int ExtendFile(PD_TYPE pd, u_int16 CCluster)
{
    ushort num;
    ushort Last;
    boolean FirstCluster=FALSE;

    DIRTYFAT(pd→PD_DTB);
    Last = CCluster;

    if(Last == FAT_LASTSECTOR){                 /*an entirely empty file */
        /*
            This will require an update to the directory as well as an update to the
            FAT.
        */
        FirstCluster = TRUE;
    }else if(FAT(CCluster, (uchar *)pd→PD_DTB→V_FATPtr) !=                  /* pg. 576 */
                FAT_LASTSECTOR)
        /*Can't extend from the middle of a file */
        return FAT_BADTRACK+1;

    if((num = GetFreeSector(pd)) < FAT_BADTRACK){                            /* pg. 574 */
        if(FirstCluster){
            DirSetFCluster(pd, num);                                         /* pg. 558 */
            pd→PD_FCluster = num;
            DIRTYFD(pd);
        }else
            SetFAT((uchar *)pd→PD_DTB→V_FATPtr, Last, num);                  /* pg. 577 */
    }
    return num;
}


static void FreeFrom(u_int16 *FATPtr, u_int16 Cluster)
{
    ushort Next;

    while(Cluster < FAT_BADTRACK){
        Next = FAT(Cluster, (uchar *)FATPtr);                                /* pg. 576 */
        SetFAT((uchar *)FATPtr, Cluster, 0);      /*Free this cluster */     /* pg. 577 */
        Cluster = Next;
    }
```

```
}


/*
    This sets the file length in the FAT. This is sufficient for directory files.
    For other files the directory entry (FD part) for the file must also be
    updated.
*/

u_int16 FATSetFileLength(PD_TYPE pd, u_int32 Length)
{
    u_int32 CurrentLength;
    u_int16 CurrentEnd, Current;

    DIRTYFAT(pd→PD_DTB);
    Length = u_bound_div(Length, SECTORSIZE * pd→PD_DTB→DD_SPC);
    CurrentEnd = ChaseToEnd((uchar *)pd→PD_DTB→V_FATPtr,            /* pg. 574 */
            pd→PD_FCluster, &CurrentLength);

    if(CurrentLength < Length) {        /*Extend the file  */
        for(; CurrentLength < Length;
                CurrentLength += (pd→PD_DTB→DD_SPC * SECTORSIZE))
            if((CurrentEnd = ExtendFile(pd, CurrentEnd)) >= FAT_BADTRACK)/* pg. 575 */
                return CurrentEnd;
    }else if(CurrentLength > Length){               /*truncate the file  */
        Current =ChaseFat((uchar *)pd→PD_DTB→V_FATPtr,                /* pg. 573 */
            pd→PD_FCluster, Length); FreeFrom((u_int16 *)pd→PD_DTB→   /* pg. 575 */
                V_FATPtr, Current);
        if(Length == 0)
            pd→PD_FCluster = FAT_LASTSECTOR;
    }

    return 0;
}


static u_int16 FAT(u_int16 Num, u_char *FATPtr)
{
    int16 x;

    if(FATPtr == NULL){
        SYSDEBUG(2, Num);
        CATASTROPHY;
    }
    x = FATPtr[(Num*3)/2] +( FATPtr[1 + (Num*3)/2] << 8);
    if(Num & 1)
        return((x >> 4) & 0x0fff);
    else
        return(x & 0x0fff);
}


static void SetFAT(u_char *FATPtr, u_int16 Num, u_int16 NewVal)
{
    if(FATPtr == NULL){
        SYSDEBUG(2, Num);
        CATASTROPHY;
    }
#ifndef FINAL
    if(Num < 2){
        SYSDEBUG(3, Num);
        CATASTROPHY;
    }
#endif
    if(Num & 1){                    /*odd cluster */
        FATPtr[1+(Num*3)/2] = (NewVal >> 4) & 0x0ff;          /*high order */
        FATPtr[(Num*3)/2] &= 0x0f;                       /*Clear high-order nyble */
        FATPtr[(Num*3)/2] |= ((NewVal << 4) & 0x0f0);
    }else {                    /*Even cluster */
        FATPtr[(Num*3)/2] = NewVal & 0x0ff;
        FATPtr[1 + (Num*3)/2] &= 0x0f0;
        FATPtr[1+ (Num*3)/2] |= ((NewVal >> 8) & 0x0f);
    }
}


int SectorInFile(u_int32 loc, u_char mode)
{
    if((mode & PD_RDIR_MODE) && !(mode & PD_RAWMODE))
        if(loc > (2 * sizeof(MSDirEntry)))
            return((loc – (2 * sizeof(MSDirEntry))) >> 9);
        else
            return 0;
    else
        return (loc / SECTORSIZE);
}

u_int32 CheckSector(PD_TYPE pd)
{
    return SectorOnDisk(pd, SectorInFile(pd→PD_CP, pd→PD_SMF));          /* pg. 578 */
}
```

```
u_int32 SectorOnDisk(PD_TYPE pd, int x)
{
    u_int32 ClusterInFile, SectorInCluster, Cluster;

    if(pd→PD_SMF & PD_RAWMODE)
        return x;
    if(pd→PD_SMF & PD_RDIR_MODE)
        if(x < (pd→PD_DTB→V_DirEntries / DIR_ENT_PER_SECTOR))
            return(MS_SECTOR(pd→PD_DTB→DD_DIR + x));
        else
            return T_FAT_LASTSECTOR;


    /* Cluster = sector divided by sectors per cluster  */
    ClusterInFile = x / pd→PD_DTB→DD_SPC;
    SectorInCluster = x % pd→PD_DTB→DD_SPC;
    Cluster = ChaseFat((uchar *)pd→PD_DTB→V_FATPtr, pd→PD_FCluster, /* pg. 573 */
            ClusterInFile);

    if(Cluster >= FAT_BADTRACK)
        return(Cluster | 0x0f000);
    else
        return MS_SECTOR(((Cluster * pd→PD_DTB→DD_SPC) + SectorInCluster +
            pd→PD_DTB→V_DataStart));
}


int ReadFAT(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    /*
        If the drive table entry for this drive already has a FAT buffer, ensure
        that it is accurate.  If it doesn't have a FAT buffer, create and load
        one.
    */

    if(pd→PD_DTB→V_FATPtr == NULL){
        if((pd→PD_DTB→V_FATPtr =
                (POINTER)_srqmem(pd→PD_DTB→V_FATSz * SECTORSIZE)) == (char *)−1)
            return E_MEMFUL;
    }
    pd→PD_DTB→V_FATLinks++;

    return(FillFAT(pd, regs, procd, SysGlobs));                        /* pg. 579 */
}
```

```
static int FillFAT(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    DriveTableType *DriveTable;
    int ReturnVal, FatSector;

    DriveTable = pd→PD_DTB;

    for(FatSector=0; FatSector < DriveTable→V_FATSz; FatSector++)
        if((ReturnVal = RawReadSector(pd,                              /* pg. 562 */
                (ulong)(MS_SECTOR(DriveTable→DD_FirstFAT + FatSector)),
                (char *)DriveTable→V_FATPtr + (FatSector * SECTORSIZE),
                regs, procd, SysGlobs)) != 0)
        return ReturnVal;

    CLEANFAT(DriveTable);
    return ReturnVal;
}


#ifdef CHECKFAT
CheckFAT(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    DriveTableType *DriveTable;
    char *ptr1, *ptr2;
    int ReturnVal, i;

    DriveTable = pd→PD_DTB;
    if((ReturnVal = RawReadSector(pd,                                  /* pg. 562 */
            MS_SECTOR(DriveTable→DD_FirstFAT),
            pd→PD_BUF, regs, procd, SysGlobs)) != 0)
        return ReturnVal;

    for(i= SECTORSIZE −1, ptr1 = pd→PD_BUF, ptr2 = pd→PD_DTB→V_FATPtr;
            i >=0; i––)
        if(*ptr1++ != *ptr2++)
            return E_DIDC;                  /*Disk ID change */

    if(DriveTable→V_FATSz >1)
        if((ReturnVal = RawReadSector(pd,                              /* pg. 562 */
                MS_SECTOR(DriveTable→DD_FirstFAT + 1),
                pd→PD_BUF, regs, procd, SysGlobs)) != 0)
            return ReturnVal;
    if(DriveTable→V_FATSz > 2)
        return E_DAMAGE; /* Something is wrong with the disk or the drive table */

    for(i= SECTORSIZE −1, ptr1 = pd→PD_BUF,
            ptr2 = (char *)pd→PD_DTB→V_FATPtr + SECTORSIZE; i >=0; i−−)
        if(*ptr1++ != *ptr2++)
            return E_DIDC;                  /*Disk ID change  */
    return 0;
}
#endif


int WriteFAT(PD_TYPE pd, REGS regs, procid *procd, void *SysGlobs)
{
    DTBPtrType DriveTable;
    int ReturnVal, FatSector;

    DriveTable = pd→PD_DTB;
#ifndef FINAL
    if(*(uchar *)DriveTable→V_FATPtr <0xf0){
        SYSDEBUG(4, DriveTable→V_FATPtr);
        CATASTROPHY;
    }
#endif

    for(FatSector = 0; FatSector < DriveTable→V_FATSz; FatSector++)
        if((ReturnVal = RawWriteSector(pd,                              /* pg. 563 */
                (ulong)(MS_SECTOR(DriveTable→DD_FirstFAT + FatSector)),
                (char *)DriveTable→V_FATPtr + (FatSector * SECTORSIZE),
                regs, procd, SysGlobs)) != 0){
            SYSDEBUG(6,pd);
            return ReturnVal;
        }
    CLEANFAT(DriveTable);
    return ReturnVal;
}


void FlushDevice(PD_TYPE pd, procid *procd, void *SysGlobs)
{
    REGISTERS regs;

    if((pd→PD_DTB→V_FATPtr != NULL) && pd→PD_DTB→V_FATDirty)
        WriteFAT(pd, &regs, procd, SysGlobs);                           /* pg. 580 */
}
```

```
void FreeFAT(DriveTableType *DriveTable)
{
    if(−−DriveTable→V_FATLinks != 0)
        return;
    if(DriveTable→V_FATPtr != NULL)
        DoSRtMem(DriveTable→V_FATPtr,                                   /* pg. 526 */
                DriveTable→V_FATSz*SECTORSIZE); DriveTable→V_FATPtr = NULL;
}
```

C.5 Special Header Files

C.5.1 Format

The format.h header file contains definitions that are specific to the PC-Dos file structure.

```
#define BOOTSECTOR          0
#define FATSTART            1
#define FILERASED           '\345'
#define DEFAULT_DRIVES      2

#define SECTORSIZE          512
#define DIR_ENT_PER_SECTOR 16

#define SYSDEBUG(a1,a2)
#define CATASTROPHY         *(char*)0xFFFFFFFF=0

/*Attributes */
#define MS_READ_ONLY        0x1
#define MS_HIDDEN           0x2
#define MS_SYSTEM           0x4
#define MS_V_LABEL          0x8
#define MS_SUBDIR           0x10
#define MS_ARCHIVE          0x20

#define FAT_BADTRACK        0x0FF7
#define FAT_LASTSECTOR      0x0FFF
#define T_FAT_BADTRACK      0x0FFF7
#define T_FAT_LASTSECTOR0x0FFFF

#define LengthenFile(pd,length) SetFileSize((pd),(length))
#define ShortenFile(pd,length) SetFileSize((pd),(length))

#ifndef TRUE
```

```
#define TRUE            1
#define FALSE           0
#endif

#ifndef NULL
#define NULL            ((void *)0)
#endif

typedef unsigned char uchar;
typedef unsigned long ulong;
typedef unsigned char boolean;


typedef struct {
    char    Reserved1[3];           /*A branch instruction                 */
    char    SystemID[8];
    uchar   SectorSize[2];          /*Bytes per sector                     */
    uchar   SectorsPerCluster;
    uchar   ReservedSectors[2];     /*Number of reserved sectors at start  */
    uchar   FATCopies;
    uchar   RootDirSize[2];         /*Number of entries in root directory  */
    uchar   TotSectors[2];          /*Sectors on the disk                  */
    uchar   FormatID;               /*F8..FF                               */
    uchar   SectorsPerFAT[2];
    uchar   SectorsPerTrack[2];
    uchar   Sides[2];
    uchar   S_ReservedSectors[2];   /*Special reserved sectors             */
}*BootSectorType;

typedef struct {
    uchar   FileName[8];
    uchar   FileExtension[3];
    uchar   FileAttr;
    char    Reserved[10];
    uchar   Time[2];
    uchar   Date[2];
    uchar   StartCluster[2];
    uchar   FileSize[4];
}*MSDirE, MSDirEntry;

/*File attributes */
#define VOL_LABEL       0x20
#define SUB_DIRECTORY   0x10
#define READ_ONLY       0x08
#define MODIFIED        0x04
```

```
#define HIDDEN              0x02
#define SYSTEM_FILE         0x01

typedef uchar SmallFAT_Entrys[3];

typedef struct {
    long      R_d0, R_d1, R_d2, R_d3, R_d4, R_d5, R_d6, R_d7;
    char      *R_a0, *R_a1, *R_a2, *R_a3, *R_a4, *R_a5, *R_a6, *R_a7;
    uchar     R_ssr;                /*Status register—system part            */
    uchar     R_cc;                 /*Status register—condition code part    */
    short     *R_pc;                /*Program counter register               */
    short     R_fmt;                /*68010 exception format and vector      */
}*REGS, REGISTERS;

typedef struct {
    uchar     DD_TOT[3];            /*Total number of sectors on device      */
    uchar     DD_TKS;               /*Track size in sectors                  */
    ushort    DD_FATSIZ;            /*Number of sectors in FAT               */
    ushort    DD_SPC;               /*Number of sectors per cluster          */
    ushort    DD_DIR;               /*Address of root directory              */
                      /*The address is actually an lsn: 24 bits              */
                      /*but since this lsn is small, 16 bits suffice         */
    ushort    DD_OWN;               /*Owner ID (meaningless)                 */
    ushort    DD_DSK;               /*Disk ID (probably meaningless)         */
    ushort    DD_ATT;               /*Attributes                             */
    uchar     DD_FMT;               /*Disk format; density/sides             */
    uchar     DD_SPT[2];            /*Sectors per track                      */
    uchar     DD_FATCnt;            /*Copies of FAT                          */
    uchar     DD_FirstFAT;          /*First FAT Sector                       */
    uchar     DD_Reserved;
    ushort    V_TRAK;               /*Current track                          */
    ushort    V_Reserved2[3];
    ushort    V_FATSz;              /*FAT size                               */
    ushort    V_DataStart;          /*First cluster in the data space        */
    ushort    V_FATLinks;           /*FAT use counter                        */
    POINTER V_ScZero;               /*Pointer to sector zero buffer          */
    boolean   V_FATDirty;           /*FAT buffer has been changed            */
    uchar     V_Init;               /*Drive initialized flag                 */
    ushort    V_Reserved5;
    ulong     V_SoftEr;
    ulong     V_HardEr;
    POINTER V_FATPtr;               /*Pointer to the drive's FAT             */
    ushort    V_DirEntries;
    ushort    V_Reserved[13];
}DriveTableType, *DTBPtrType;

typedef struct {
    /* I/O Device Static storage required by the kernel for all device types. */
    POINTER V_PORT; /*Device base port address */
    ushort    V_LPRC;              /*Last active process ID                    */
    ushort    V_BUSY;              /*Current process ID (0=idle)               */
    ushort    V_WAKE;              /*Active process ID if driver must wakeup   */
    POINTER V_Paths;               /*Linked list of open paths on device       */
    ulong     V_Reserved[8];
    /*Static storage for RBF drivers */
    uchar     V_NDRV;              /*Number of drives                          */
    uchar     V_DReserved[7];
    DriveTableType V_DRIVES[DEFAULT_DRIVES]; /* This may be the wrong size,
                                                                  but that's ok */
    /*Followed by device driver static storage */
}*STATICSTORETYPE;

typedef struct {
    char      *I_DevTbl;           /*Pointer to Default device table           */
    ulong     DirCluster;          /*First cluster for directory               */
    ulong     Extra[2];            /*Unused space.                             */
}DefaultDescriptor;
```

C.5.2 PathDesc

This pathdesc.h file contains the path descriptor format used by the msfm file manager.

```
#define PATHDELIM '/'
#define ENTIRE_DELIM '@'

#define MS_SECTOR(n) ((n) – 1)         /*Convert pcdos sector # to OS-9 sector #   */
#define FDOFFSET(x)             ((x)&0x0f)
#define FDSECTOR(x)             ((x) >> 4)
#define MAKE_FD_HASH(sect,off)(((sect) << 4)|((off)&0x0f))

typedef struct {
    uchar vfd_att,
          vfd_own[2],
          vfd_date[5],
          vfd_link,
          vfd_fsize[4],
          vfd_dcr[3],
          vfd_cluster[2];
```

```
}VirFD, *VirFDPtr;

typedef struct PDTYPE {
    ushort    PD_PD;                  /*Path number                        */
    uchar     PD_MOD;                 /*Mode (read/write/update)           */
    uchar     PD_CNT;                 /*Number of open images              */
    struct DEVTAB *PD_DEV;            /*Device table entry address         */
    ushort    PD_CPR;                 /*Current process ID                 */
    POINTER PD_RGS;                   /*Caller's register stack pointer    */
    char      *PD_BUF;                /*Buffer address                     */
    ulong     PD_USER;                /*User ID of path's creator          */
    struct PDTYPE *PD_Paths;          /*L-List of paths to this device     */
    ushort    PD_COUNT;               /*Actual number of open images       */
    ushort    PD_LProc;               /*Last active process ID             */
    short     PD_Reserved[6];

    /*
        File manager storage
    */

    uchar     PD_SMF;                 /*State flags                        */
    uchar     PD_Unused;
    ushort    PD_Parent;              /*FCluster of parent dir             */
    ulong     PD_CSector;             /*Number of sector in the buffer     */
    ulong     PD_CP;                  /*Current logical byte position      */
    ulong     PD_SIZ;                 /*File size                          */
    short     PD_CCluster;            /*Current cluster                    */
    MSDirE  PD_FDBUF;                 /*Buffer for file descriptor info    */
    ulong     PD_FDSector;            /*Sector number for above FDs        */
    ulong     PD_FDOffset;            /*Offset in sector for FD below      */
    DTBPtrType PD_DTB;                /*Drive table pointer                */
    ulong     PD_FDHash;              /*Combined sector/offset             */
    uchar     PD_Accs;                /*Allowable file access permissions  */
    VirFD     PD_FD;                  /*First part of virtual OS-9 FD      */

    /*
        The fields so far add up to 35+18=53 bytes of file manager storage.
        86 bytes are required to bring us up to the option area.
    */

    char      PD_Unused2[29];         /*86 – 35 - 22                       */

    /*
        Path descriptor's options section
    */
    uchar    PD_DTP;              /*Device type                          */
    uchar    PD_DRV;              /*Drive number                         */
    uchar    PD_STP;              /*Step rate                            */
    uchar    PD_TYP;              /*Disk device type                     */
    uchar    PD_DNS;              /*Density capability                   */
    char     PD_NewLine;          /*New line character for Rd/Writ-Ln    */
    ushort   PD_CYL;              /*Number of cylinders                  */
    uchar    PD_SID;              /*Number of sides                      */
    uchar    PD_VFY;              /*0=verify disk writes                 */
    ushort   PD_SCT;              /*Default sectors per track            */
    ushort   PD_TOS;              /* "" "" (tr0, s0)                     */
    ushort   PD_SAS;              /*Segment allocation size              */
    uchar    PD_ILV;              /*Sector interleave offset             */
    uchar    PD_TFM;              /*DMA transfer mode                    */
    uchar    PD_TOffs;            /*Track base offset                    */
    uchar    PD_SOffs;            /*Sector base offset                   */
    ushort   PD_SSize;            /*Size of sector in bytes              */
    ushort   PD_Cntl;             /*Control word                         */
    uchar    PD_Trys;             /*Number of tries (1=no error corr)    */
    uchar    PD_LUN;              /*SCSI unit number of drive            */
    ushort   PD_WPC;              /*First cylinder using write precomp   */
    ushort   PD_RWC;              /* "" "" reduced write current         */
    ushort   PD_Park;             /*Park cylinder for hard disks         */
    ulong    PD_LSNOffs;          /*LSN offset for partition             */
    ushort   PD_TotCyls;          /*Total cylinders on device            */
    uchar    PD_CtrlrID;          /*SCSI controller ID                   */
    uchar    PD_reserved3[14];
    uchar    PD_ATT;              /*File attributes                      */
    ulong    PD_FCluster;         /*Starting cluster (was PD_FD)         */
    ulong    PD_DFD;              /*Directory FD psn                     */
    ulong    PD_DCP;              /*Directory entry pointer              */
    POINTER PD_DVT;               /*Device table pointer (copy)          */
    uchar    PD_reserved4[26];
    uchar    PD_Name[12];         /*Filename                             */
    char     PD_NotName[20];      /*Leftover space                       */
}*PD_TYPE;

#define PD_RAWMODE        0x01
#define PD_DIR_MODE       0x02          /*Any directory                  */
#define PD_RDIR_MODE      0x04          /*The ROOT directory             */
#define PD_DIRTYFD        0x08          /*The FD copy in the PD is dirty */
#define PD_GOODBUF        0x10          /*The data in FD_BUF is valid    */
#define DIRTYFD(pd)       (pd)->PD_SMF|=PD_DIRTYFD
#define CLEANFD(pd)       (pd)->PD_SMF&=~PD_DIRTYFD
```

```
typedef struct DEVTAB {
    POINTER             V_DRIV;
    STATICSTORETYPE V_STAT;
    POINTER             V_DESC;
    POINTER             V_FMGR;
    short               V_USRS;
}*DEVTABTYPE;

#include "prototypes.h"
```

C.5.3 Prototypes

This prototyptes.h file contains the ANSI function prototypes for all externally visible functions.

```
int Close(PD_TYPE, REGS, void *, void *);
int Create(PD_TYPE, REGS, procid *, void *);
int Delete(PD_TYPE, REGS, procid *, void *);
int Errno(u_int32);
u_int16 FATSetFileLength(PD_TYPE, u_int32);
u_int32 CheckSector(PD_TYPE);
u_int32 SectorOnDisk(PD_TYPE, int);
int ReadFAT(PD_TYPE, REGS, procid *, void *);
int CheckFAT(PD_TYPE, REGS, procid *, void *);
int WriteFAT(PD_TYPE, REGS, procid *, void *);
void FlushDevice(PD_TYPE, procid *, void *);
void FreeFAT(DriveTableType *);
int MakDir(PD_TYPE, REGS, procid *, void *);
int MakDirBlanks(MSDirE, int, PD_TYPE, REGS, procid *, void *);
void MakDotDir(MSDirE, PD_TYPE);
int Read(PD_TYPE, REGS, procid *, void *);
int OffsetInSector(PD_TYPE);
int RawReadSector(PD_TYPE, u_int32, char *, REGS, procid *, void *);
int ReadSector(PD_TYPE, u_int32, char *, REGS, procid *, void *);
int ReadLn(PD_TYPE, REGS, procid *, void *);
void SectorMs2os9(PD_TYPE, MSDirE);
void Dir2FD(VirFDPtr, MSDirE);
void UpdateDirEntFromPD(MSDirE, PD_TYPE);
u_int32 FakeRootDir(u_int32, u_int16 *, char **);
int WriteIntoDir(int32, int32, char *, char *);
int Write(PD_TYPE, REGS, procid *, void *);
int SetFileSize(PD_TYPE, u_int32);
int WritePrepare(PD_TYPE, u_int16);
int W_PrepareDir(PD_TYPE, u_int16);
```

```
boolean NameMatch(u_char *, u_char *);
int AdjustAttributes(u_char);
u_char ReAdjustAttributes(u_char);
void SetRootDir(PD_TYPE, procid *, char);
int FindEmpty(PD_TYPE, REGS, procid *, void *);
int MakDirEntry(PD_TYPE, REGS, procid *, void *);
int UpdateFD(PD_TYPE, REGS, procid *, void *);
void DirSetFileOwner(PD_TYPE, int);
void DirSetFileLink(PD_TYPE, int);
void DirSetFileDate(PD_TYPE, char dt[5]);
void DirSetCrDate(PD_TYPE, char dt[5]);
void DirSetFCluster(PD_TYPE, u_int16);
void DirSetFileLength(PD_TYPE, u_int32);
void DirSetFileAttr(PD_TYPE, u_int16);
int WriteDirEntry(MSDirE, u_int32, int16, PD_TYPE, REGS, procid *, void *);
void InitFromBoot(PD_TYPE, BootSectorType, REGS, procid *, void *);
int ChgDir(PD_TYPE, REGS, procid *, void *);
int Seek(PD_TYPE, REGS, procid *, void *);
int GetStat(PD_TYPE, REGS, procid *, void *);
int SetStat(PD_TYPE, REGS, procid *, void *);
int DriverSetStat(PD_TYPE, REGS, procid *, void *);
int DriverGetStat(PD_TYPE, REGS, procid *, void *);
int Open(PD_TYPE, REGS, procid *, void *);
int FindFile(PD_TYPE, REGS, procid *, void *);
int InitPD(PD_TYPE);
int ParseName(PD_TYPE, REGS, procid *, void *);
int CheckAccess(PD_TYPE, u_int32);
int CheckSecurity(PD_TYPE, u_char);
int strncmp(u_char *, u_char *, u_int32);
int ncstrcmp(u_char *, u_char *);
char toupper(char);
boolean islegal(char);
u_int32 u_bound_div(u_int32, int32);
int array_to_int(u_char *, u_int16);
void int_to_array(u_char *, int, int);
void change_sex_2ia(u_char *, int);
int GetFD(PD_TYPE, REGS, procid *, void *, u_int32);
int MoveData(void *, const void *, u_int32);
```

C.6 The Device Descriptor

```
                    opt     -l
00000001  TrkDns    set     1               double track density
```

```
00000001  BitDns    set    1               Double bit density
00000003  Density   set    BitDns+(TrkDns << 1)
00000026  DiskType  set    %00100110       Non-standard 5" floppy

00000f00  TypeLang  set    (Devic << 8)+0
00008001  Attr_Rev  set    (ReEnt << 8)+1
00000001  Edition   set    1

                    psect  MSFDesc,TypeLang,Attr_Rev,Edition,0,0

fff47006  Port      set    $FFF47006
00000065  Vector    set    101
00000002  IRQLevel  set    2
00000005  Priority  set    5
000000b7  Mode      set    Append_+Dir_+ISize_+Exec_+Updat_
00000000  DrvNum    set    0
00000003  StepRate  set    3
00000050  Cylinders set    80
00000002  Heads     set    2

0000 fff4           dc.l   Port            port address
0004   65           dc.b   Vector          auto-vector trap assignment
0005   02           dc.b   IRQLevel        IRQ hardware interrupt level
0006   05           dc.b   Priority        irq polling priority
0007   b7           dc.b   Mode            device mode capabilities
0008 0054           dc.w   FileMgr         file manager name offset
000a 004d           dc.w   DevDrv          device driver name offset
000c 0059           dc.w   DevCon          (reserved)
000e 0000           dc.w   0,0,0,0         reserved
0016 0035           dc.w   OptLen

          * Default Parameters
          OptTbl
0018=   00          dc.b   DT_RBF          device type
0019   00           dc.b   DrvNum          drive number
001a   03           dc.b   StepRate        step rate
001b   26           dc.b   DiskType        type of disk 8"/5"/Hard
001c   03           dc.b   Density         Bit Density and track density
001d   0d           dc.b   13              New Line character
001e 0050           dc.w   Cylinders       number of cylinders
0020   02           dc.b   Heads           Number of Sides (Floppy) Heads(Hard Disk)
0021   01           dc.b   1               Don't verify writes
0022 0012           dc.w   18              Sectors per track
0024 0012           dc.w   18              Sectors per track (0)
0026 0002           dc.w   2               Segment allocation size
0028   01           dc.b   1               Sector interleaving factor
0029   00           dc.b   0               No DMA
002a   00           dc.b   0               Track offset
002b   01           dc.b   1               Sector offset (sectors start at 1, not 0)
```

```
002c 0200          dc.w   512             Sector size
002e 0002          dc.w   2               Control word
0030   01          dc.b   1               Number of tries
0031   00          dc.b   0               SCSI unit number of drive
0032 0000          dc.w   0               first cylinder using write precomp
0034 0000          dc.w   0               first cylinder using reduced write current
0036 0000          dc.w   0               park cylinder for hard disks
0038 0000          dc.l   0               logical sector number offset for partition
003c 0050          dc.w   80              total number of cylinders on device
003e   06          dc.b   6               scsi controller id
003f   30          dc.b   $30             data-transfer & rotational rates
0040 0000          dc.l   $00000001       SCSI driver option flags
0044 00ff          dc.l   $00ffffff Maximum byte count passable to driver.
0048   00          dc.b   0
0049   00          dc.b   0
004a   00          dc.b   0
004b   00          dc.b   0
004c   00          dc.b   0
00000035  OptLen   equ    *-OptTbl
004d 7262 DevDrv   dc.b   "rbteac",0
0054 6d73 FileMgr  dc.b   "msfm",0
0059 7363 DevCon   dc.b   "scsi167",0
00000062           ends
```

Appendix D

Sample RBF Device Driver

This chapter contains a complete device driver for the NEC 765 floppy disk controller. It contains many of the common features of RBF device drivers.

The device driver in this chapter is Microware's standard NEC 765 FDC device driver for OS-9/68k version 2.1.[1] Subsequent releases of OS-9 may have slightly different requirements for the device driver. Microware supports most older device drivers with options and compatibility modes, but up-to-date drivers work best.

D.1 Module Header

A device driver should have a module type of Drvr and the ReEnt and SupStat attributes.

The stack size in the `psect` directive should be zero. The device driver uses the caller's system stack[2] except in its interrupt routine. The interrupt routine uses the master system stack.

The amount of stack space available to the driver depends on the size of the system stack in the process descriptor (about a kilobyte) and the stack requirements of the kernel, IOMan, and the file manager. The safest policy is to keep stack consumption below about 256 bytes.

```
                    nam     NEC-765
                    ttl     Driver Module
0000000a  Edition   equ     10                  current edition number

00000e01  Typ_Lang  set     (Drivr << 8)+Objct Device Driver In Assembly Language
```

[1] This source code is the proprietary confidential property of Microware Systems Corporation, and is provided to licensee solely for documentation and educational purposes. Reproduction, publication, or distribution in any form to any party other than the licensee is strictly prohibited.

[2] A process' system stack is in its process descriptor

```
0000a000  Attr_Rev  set     ((ReEnt+SupStat) << 8)+0

                    psect   NEC765,Typ_Lang,Attr_Rev,Edition,0,DiskEnt

                    use     defsfile
```

The defsfile includes oskdefs.d and systype.d.

D.2 Static Storage

The device static storage contains fields that are related to the device (as opposed to the path).

```
00000002  DriveCnt  equ     2                        *** Must be linked with for two drives ***
00000000  True      equ     0
00000001  False     equ     1


****************************************************************
*
* This Controller Uses A Nec 765 FDC
*

***************
* Static Storage definitions

                    vsect
00000000  V_BUF     ds.l    64          addr of local buffer
00000100  V_LSN     ds.l    1           logical sector #
00000104  V_IMask   ds.w    1           interrupt Mask Value
00000106  V_Side    ds.b    1           side select value
00000107  V_Sector  ds.b    1           sector buffer
00000108  V_Track   ds.b    1           track buffer
00000109  V_TfrMod  ds.b    1           0=No Transfer 1=read 2=write
0000010a  V_CurDrv  ds.b    1           drive select bit
0000010b  V_Count   ds.b    1           count byte for moves
0000010c  V_Size    ds.b    1           current disk size 0:=5"
0000010d  V_DOSK    ds.b    1           force seek flag
0000010e  V_FREZ    ds.b    1           freeze dd. info flag
0000010f  V_IRQ     ds.b    1           1 = process command with IRQ's
00000110  V_CMDSIZ  ds.b    1           size of FDC command
00000111  V_SPCFY   ds.b    1           if 0 have not initialized NEC 765

* Nec command buffers
00000112  Command1  ds.b    1
00000113  Command2  ds.b    1
00000114  Command3  ds.b    1
```

```
00000115  Command4 ds.b     1
00000116  Command5 ds.b     1
00000117  Command6 ds.b     1
00000118  Command7 ds.b     1
00000119  Command8 ds.b     1
0000011a  Command9 ds.b     1

* Nec result buffers
0000011b  Results   ds.b    9
00000000            ends
```

D.3 Definitions

```
***************
* VME8400 register layouts
*

00000000  MSR       equ     0          NEC765 main status register
00000002  DataReg   equ     2          NEC765 Data Register
00000004  TermCnt   equ     4          issue end of read or write
00000008  MotorCtl  equ     8          5 1/4 motor control 0= motor off
0000000c  IntEnabl  equ     $C         interrupt enable/disable 0=disable

***************
* Nec 765 Commands
*
00000003  F.Specfy  equ     $03        specify command
00000007  F.Rest    equ     $07        restore cmd
0000000f  F.Seek    equ     $0F        seek cmd
00000006  F.ReadSc  equ     $06        read sector
00000005  F.WrtSec  equ     $05        write sector
0000000d  F.WrtTrk  equ     $0D        write track
00000040  DDensity  equ     $40        double density bit in command byte
00000004  F.SnsDrv  equ     $04        sense drive status
00000008  F.SnsIRQ  equ     $08        sense interrupt status
00000001  N         equ     $01        256 bytes/sector
00000064  HLT       equ     100        head load time * 2 ms (100 * 2)
00000001  NonDMA    equ     1          non dma flag
000000e5  Filler    equ     $E5        sector fill byte
0000001e  GPL8SD    equ     30         gap length for format
00000032  GPL8DD    equ     50         gap length for format
0000000f  GPL5SD    equ     15
0000000a  GPL5DD    equ     10
0000000a  GPL       equ     $A         gap length for 5&8" drives
000000ff  DTL       equ     $FF        data length n/a for 256 byte sects
0000000f  EOTSD8    equ     $0F        last sect on track 8" sd
0000001a  EOTDD8    equ     $1A        last sect on track 8" dd
```

```
0000000a  DelayTim  equ     10              time to delay between commands

* Nec Status register bits

00000001  D0B       equ     $1              drive zero in seek mode
00000002  D1B       equ     $2              drive one in seek mode
00000004  D2B       equ     $4              drive two in seek mode
00000008  D3B       equ     $8              drive three in seek mode
00000010  CB        equ     $10             read or write in progress
00000020  NDM       equ     $20             FDC in non-DMA mode
00000040  DIO       equ     $40             0 = processor > FDC
00000080  RQM       equ     $80             data register ready

00000005  Busy_Bit  equ     5
00000005  Seek_Bit  equ     5
00000004  CB_Bit    equ     4
00000006  DIO_Bit   equ     6

00000000  PDDN_Bitequ       0               density bit in path descriptor

00000080  Invalid   equ     $80             invalid command code

* Nec Error register bits

000000c0  IC        equ     $C0             command completion status
00000080  EN        equ     $80             end of cylinder
00000040  EC        equ     $40             fault or bad restore
00000020  DE        equ     $20             CRC error
00000008  NR        equ     $08             device not ready
00000004  ND        equ     $04             seek error
00000002  NW        equ     $02             write protect
00000001  MA        equ     $01             missing address (seek error)

* Command code bits

00000006  MF_Bit    equ     6               format bit 0=single density 1=double density
00000007  MT_Bit    equ     7               multi track bit

* Error code bits
00000000  MA_Bit    equ     0               missing address mark
00000001  NW_Bit    equ     1               disk write protected
00000002  ND_Bit    equ     2               no data
00000003  NR_Bit    equ     3               not ready
00000004  EC_Bit    equ     4               equipment check
00000005  DE_Bit    equ     5               data error (crc error)

* Bit numbers for DD_FMT
```

```
00000000  Side_Bit   equu      0                  0=single 1=double
00000001  Dens_Bit   equ       1                  0=single 1=double
00000002  Trks_Bit   equ       2                  0=48 tpi 1=96 tpi

* Bit numbers for path descriptors

00000000  Size_Bit   equ       0                  0=5 inch 1=8"
```

D.4 The Vector Table

A device driver offers several services, but it has only one entry point specified in its module header. The problem is resolved through indirection. The module entry point offset does not locate code, instead it points to the following table. The table contains a list of offsets, one for each standard entry point in an RBF device driver.[3]

```
*
* Branch Table
*
0000 000e  DiskEnt   dc.w      InitDisk           initialize I/O
0002 00e4            dc.w      ReadDisk           read sector
0004 0088            dc.w      WritDisk           write sector
0006 047e            dc.w      GetStat            get status
0008 046c            dc.w      PutStat            put status
000a 0570            dc.w      Term               terminate device
000c 0000            dc.w      0                  exception handler (0=none)
```

D.5 Device Initialization

The device initialization routine is called by IOMan when the device is attached (usually when it used for the first time).

The initialization routine is responsible for initializing data structures that have not been filled by IOMan and RBF, and putting its I/O hardware into the initial state defined in the path descriptor options section.

The drive table is maintained by the device driver. This table reflects the fact that IOMan treats all the drives attached to a controller as a single device. In particular, it assigns them one common device static storage. This has advantages in that the floppy disk controller (FDC) has a common set of control and status registers for all the disks,

[3]OS-9/68k does not use the same strategy for its vector table that OS-9/6809 used. The older OS-9 put actual branch instructions in the table. Now the table contains offsets. This gives a small savings in memory.

and only one of the disks can be in use at any time. The shared device static storage includes a drive table. The drive table stores the characteristics that may vary from drive to drive.[4]

The first thing the initialization routine does is fill the drive table with default values: current drive, size, and high track are all given impossible values. Useful data will be inserted in the drive table when the driver reads sector zero (the system sector).

```
* Initialize
*
* Input:
* (a1) = Device descriptor
* (a2) = Static Storage ptr
* (a6) = System global data pointer
*
                InitDisk:
000e=266a              movea.l V_PORT(a2),a3  point to controller ports
0012 7002              moveq   #DriveCnt,d0
0014=1540              move.b  d0,V_NDRV(a2) init # of drives

* initialize drive tables

0018 72ff              moveq   #$FF,d1         init fake media size
001a 1541              move.b  d1,V_CurDrv(a2)init high drive #
001e=41ea              lea     DRVBEG+DD_TOT(a2),a0 point at first table
0022 1081 Init10       move.b  d1,(a0)         set up size
0024=1141              move.b  d1,V_TRAK(a0)  set high track #
0028=41e8              lea     DRVMEM(a0),a0 move to next table
002c 5300              subq.b  #1,d0           last drive?
002e 66f2              bne.s   Init10          branch if not
```

The init routine configures the FDC by setting the stepping rate [5] and indicating that DMA will not be used. The stepping rate is stored in the device descriptor and copied into the path descriptor's option area when the path is opened. The following block of code fetches the stepping rate from the device descriptor (the init routine doesn't see the path descriptor), and converts it from the device-independent descriptor code into a value that has meaning to the controller. It adds a flag that causes the controller to use programmed I/O and forwards the command to the FDC using a routine that is shared among all the code that manipulates the controller.

[4]The drive table is, for the most part, a copy of the system sector on the disk, but it also includes a set of reserved fields. These are for Microware's use.

[5]Note that stepping rate is a characteristic of the NEC765 FDC, not a drive. This fixed stepping rate could cause trouble in a system with several different drives attached to one controller. The controller would be forced to a stepping rate low enough for the slowest drive on the controller. Most drivers do not set the stepping rate in INIT.

```
0030 7e00          moveq   #0,d7             clear transfer mode
0032 7000          moveq   #0,d0
0034=1029          move.b  PD_STP−PD_OPT+M$DTyp(a1),d0 step rate from desc
0038 41fa          lea     RateTabl(pcr),a0 point to baud rate table
003c 1570          move.b  (a0,d0.w),Command2(a2) move step and head load vals
0042 157c          move.b  #HLT+NonDMA,Command3(a2) head ld & no-dma flag
0048 157c          move.b  #F.Specfy,Command1(a2) put last command in buffer
004e 7803          moveq   #3,d4             load command count
0050 6100          bsr     DoComand          process the command
0054 6524          bcs.s   BadUnit           exit if error
```

The FDC will raise an interrupt when it completes certain operations. The F$IRQ SVC must be used to inform the kernel that these interrupts should be forwarded to the driver's interrupt handler.

```
* Set up for IRQ's
0056 7000          moveq   #0,d0
0058 1400          move.b  d0,d2
005a=1029          move.b  M$Vector(a1),d0 get irq vector number from descriptor
005e=1429          move.b  M$IRQLvl(a1),d2 get hardware irq level
0062 e14a          lsl.w   #8,d2             shift to irq mask
0064=08c2          bset    #SupvrBit+8,d2    set system state bit
0068 3542          move.w  d2,V_IMask(a2)    save for future use.
006c=1229          move.b  M$Prior(a1),d1
0070 41fa          lea     IRQSrvc(pcr),a0   point to IRQ routine
0074=4e40          os9     F$IRQ             get on the table
0078 4e75  Return  rts

           BadUnit
007a=323c          move.w  #E$Unit,d1
007e=003c          ori     #Carry,ccr        set carry
0082 4e75          rts                       exit with error
```

This table is used to convert the stepping rate value in the device descriptor into values suitable for the NEC 765.

```
           RateTabl
0084 48            dc.b    $48               12 ms step rate
0085 98            dc.b    $98               9 ms step
0086 a8            dc.b    $A8               6 ms step
0087 d8            dc.b    $D8               3 ms step
```

D.6 Write Sector

This routine is called by the file manager to write a sector to the disk. It is responsible for converting a logical sector number into side/track/sector coordinates,[6] seeking to the required track, and transferring the data. If write-verify is enabled, the driver reads the sector into the verify buffer after writing it from the primary buffer, and compares the read buffer to the write buffer.

Since most of the details of reading and writing are common—start the motor, calculate the track, seek (maybe restore), calculate the side and issue a read or write command—they share a routine called XfrSec that performs the common tasks.

```
* Write Sector
*
* Input:
* (d0.l) = Number of contiguous sectors to write
* (d2.l) = logical sector #
* (a1) = path descriptor
* (a2) = Static Storage ptr
* (a4) = Process descriptor pointer
* (a5) = Caller's register stack pointer
* (a6) = System global data storage pointer
*
               WritDisk:
0088 2f02              move.l   d2,-(a7)          save sector #
008a 6608              bne.s    Write10           branch if not writing sect 0
008c=0829              btst     #FmtDis_B,PD_Cntl+1(a1) ok to write sect 0
0092 6642              bne.s    Write99           no goto error rpt routine
0094 7605 Write10      moveq    #F.WrtSec,d3      write a sector cmd
0096 7e02              moveq    #2,d7             flag disk write
0098=2a69              movea.l  PD_BUF(a1),a5     point to buffer
009c 6170              bsr.s    XfrSec            transfer sector
009e 4cdf              movem.l(a7)+,d2            restore sector #
00a2 6530              bcs.s    WritErr           leave if error
00a4=4a29              tst.b    PD_VFY(a1)        verify ?
00a8 6628              bne.s    WritExit          no, leave
00aa 4bea              lea      V_BUF(a2),a5      point to verify buffer
00ae 6138              bsr.s    ReadDs10          re-read the written block
00b0 651a              bcs.s    VerifyEr          exit with error
00b2 4bea              lea      V_BUF(a2),a5
00b6=2069              movea.l  PD_BUF(a1),a0     point to original buffer
00ba 303c              move.w   #256/4,d0         get # of bytes to check
00be 6004              bra.s    Verify10
00c0 5340 VerifyLp     subq.w   #1,d0
00c2 670e              beq.s    WritExit          branch if so
00c4 bb88 Verify10     cmpm.l   (a0)+,(a5)+       is data the same?
```

[6] Sometimes the conversion from LSN to side/track/sector is done by the controller or the drive.

† *XfrSec*: see page 601

```
00c6 67f8              beq.s    VerifyLp        branch if so
00c8=323c              move.w   #E$Write,d1     flag write error
00cc=003c VerifyEr     ori      #Carry,ccr      flag error
00d0 6002              bra.s    WritErr

00d2 7200 WritExit     moveq    #0,d1           no errors
00d4 4e75 WritErr      rts
00d6 4fef  Write99     lea      4(a7),a7        restore stack ptr
00da=323c              move.w   #E$Format,d1    flag write error
00de=003c              ori      #Carry,ccr
00e2 4e75              rts
```

D.7 Read Sector

Unless the driver is reading sector zero, the entire function of ReadDisk is performed by XfrSec. The driver simply sets up the parameters to read a sector and branches to XfrSec. The rts at the end of XfrSec returns to the file manager.

If the driver is reading sector zero, it must update the drive table from the system information in sector zero. The contents of the system sector are simply copied from the primary buffer into the drive table entry for this drive.

```
*
* Read Sector
*
* Input:
* (d0.l) = number of contiguous sectors to read
* (d2.l) = logical sector #
* (a1) = path descriptor
* (a2) = Static Storage ptr
* (a4) = Process descriptor pointer
* (a5) = Caller's register stack pointer
* (a6) = System global data storage pointer
*
               ReadDisk:
00e4=2a69              movea.l  PD_BUF(a1),a5
00e8 7606 ReadDs10     moveq    #F.ReadSc,d3    get NEC read command
00ea 7e01              moveq    #1,d7           flag disk read
00ec 4a82              tst.l    d2              reading sector 0
00ee 661e              bne.s    XfrSec          branch if not
00f0 611c              bsr.s    XfrSec          read sector 0
00f2 6518              bcs.s    ReadDs99        exit if error

* UpDate Drive Table
* a0 points to drive table
```

[†] *XfrSec*: see page 601

```
***
* Here If Sector 0 Being Read
*
          Read20
00f4=2069           movea.l PD_DTB(a1),a0
00f8=2669           movea.l PD_BUF(a1),a3  point to sector buffer
00fc=323c           move.w  #DD_SIZ−1,d1   copy this many+1
0100 11b3 Read30    move.b  (a3,d1.w),(a0,d1.w)
0106 51c9           dbra    d1,Read30      branch if not
010a 7200           moveq   #0,d1          clear carry
010c 4e75 ReadDs99  rts
```

D.8 Service Routines for Read and Write

The preceeding read and write routines were very short blocks of code. If that seems to indicate that reading and writing with the NEC 765 is absurdly easy, you have been deceived. There is plenty of support code shared between the two routines.

The transfer routine is the top-level routine of the support code. Read sector and write sector load up registers with parameters and `bsr` (or `bra`) to XfrSec.

The code in XfrSec is almost device independent. The more intelligent hard disk controllers are simpler than this because they read and write sectors by sector number. This version of XfrSec calls for a seek and calculates the side. The controller scans the track and picks out the sector.

The outline of XfrSec is:

```
Turn on the drive’s motor.
Set the retry pattern.
Get a pointer to the drive table entry for this drive.
If the LSN is not zero
Retry_point:
    If the LSN is out of range
        declare an error and return to the caller.
    If the LSN < sectors on track 0
        track = 0
        Sector = LSN
    Else
        Sector = LSN – sectors on track 0.
        If(Sector != 0)
            Track = 1 + (Sector / sectors per track).
            If double sided disk
                Side = low bit of Track;
                Track = Track / 2.
        Sector = Sector mod Sectors per track.
    Seek to track.
    Setup command buffer.
    Do the transfer.
    If there was a recoverable error anywhere
        Restore and retry then just retry 3 times.
        Then restore and do the sequence again.
        Then just keep restoring and retrying.
```

The retry logic is a little different from the official specification. This driver only consults the number of retries specified in the device descriptor to determine whether it should retry at all, not to govern the number of retries.[7]

The retries are controlled by a bit of tricky assembly language. The retry pattern is initialized to $EE, or %11101110 in binary. Before each retry the driver shifts the retry pattern one bit to the right. If it shifts a zero out the right side, the driver restores the head to track zero before retrying. If it shifts a one out the right side, the driver just retries from the seek..

The XfrSec block calls Restore, Select, SetTrk, SetUp, and DoCommand.

```
*
* Transfer Sector
*
* Input:
* (d0.b) = Read or Write Command
* (d2.l) = logical sector #
* (a1) = path descriptor
* (a2) = Static Storage ptr
* (a5) = data buffer
010e 2542 XfrSec:   move.l  d2,V_LSN(a2)     buffer LSN
0112=266a           movea.l V_PORT(a2),a3
0116 177c           move.b  #1,MotorCtl(a3)  turn on motors (5")
011c 7cee           moveq   #$EE,d6          set retry pattern
011e 600c           bra.s   XfrSec20
0120 6100 XfrSec10  bsr     Restore          reset to track zero
0124 6500           bcs     SectEr10         branch if error
0128 242a XfrSec15  move.l  V_LSN(a2),d2     restore LSN
012c 6100 XfrSec20  bsr     Select           get drive table pointer
0130 4a82           tst.l   d2               reading sector 0
0132 6740           beq.s   XfrSec40         branch if so
0134=2028           move.l  DD_TOT(a0),d0get total # of sectors
0138 e088           lsr.l   #8,d0            adjust for 3 byte value
013a b082           cmp.l   d2,d0            sector out of range?
013c 6366           bls.s   SectErr          branch if so
013e 7000           moveq   #0,d0
```

[7]It appears that this driver will do an unlimited number of retries if neccessary.

```
0140 1540            move.b  d0,V_Track(a2)   clear track number
0144 7a00            moveq   #0,d5            clear all of d5
0146=3a29            move.w  PD_T0S(a1),d5    get # of sectors in Trk 0
014a 4a82            tst.l   d2               are we reading sector 0?
014c 672c            beq.s   XfrSec50         branch if so
014e ba82            cmp.l   d2,d5            is sector in track 0
0150 6228            bhi.s   XfrSec50         branch if so
0152 9485            sub.l   d5,d2            subtract track 0 sectors
0154 670a            beq.s   XfrSec30         if not zero continue
0156=1a28            move.b  DD_TKS(a0),d5
015a 6700            beq     BadUnit          exit with error
015e 84c5            divu    d5,d2            find track #
0160 5242 XfrSec30   addq.w  #1,d2            count track
0162=0828            btst    #Side_Bit,DD_FMT(a0) is it double sided?
0168 670a            beq.s   XfrSec40         branch if not
016a e24a            lsr.w   #1,d2            adjust track number
016c 6406            bcc.s   XfrSec40         branch if side 0
016e 157c            move.b  #4,V_Side(a2)    set side flag
0174 1542 XfrSec40   move.b  d2,V_Track(a2)
0178 4842            swap    d2               get sector # in lower word
017a 1542 XfrSec50   move.b  d2,V_Sector(a2)
017e 6100            bsr     SetTrk           move to track
0182 650a            bcs.s   XfrSec60         branch if error
0184 612c            bsr.s   SetUp            set up command buffer
0186 6520            bcs.s   SectEr10         exit with error
0188 6100            bsr     DoComand         do transfer
018c 6410            bcc.s   XfrSec70         branch if no error
018e=0c29 XfrSec60   cmpi.b  #1,PD_Trys(a1)
0194 6716            beq.s   XfrSecEr
0196 e20e            lsr.b   #1,d6            shift retry
0198 6486            bcc.s   XfrSec10         branch if restore
019a 668c            bne.s   XfrSec15         branch if retry
019c 600a            bra.s   SectEr10

          XfrSec70
01a0 422b            clr.b   MotorCtl(a3)     shut off motors
01a2 4e75            rts

01a4=323c SectErr    move.w  #E$Sect,d1       flag sector out of range
01a8 422b SectEr10   clr.b   MotorCtl(a3)     shut off motors
01ac=003c XfrSecEr   ori     #Carry,ccr
01b0 4e75            rts
```

Setup is called only from XfrSec. It fills in the command buffer for the read or write command as specified in D3. It turns out that the *only* difference between a read command buffer and a write command buffer for the same sector is the code in the Command1 position in the command buffer.

The outline of the code is:

```
Setup(CmdByte)
    If Side = 1
        If the drive doesn't support double sided
            declare an error
        The drive number is already in Command2
        Command2 = Command2 or Side
    Command4 = Side / 4
    Command3 = Track
    if Double Density Disk
        Set DD bit in CmdByte
    Command5 = Sector + SectorOffset
    Command6 = bytes per sector (* div 256 *)
    Command7 = Sector
    Command8 = physical format gap length
    Command9 = physical format data length
    Command1 = CmdByte
    return 9 (* Command size *)
```

There are a few non-obvious places in this code.

- The drive number is set in Command2 by the Select routine which must be called before Setup.

- The side number in PD_SID is set by the caller. It is zero for side zero or four for side one. Floppy disk controllers usually address up to four drives numbered zero through three. Or'ing a four with the drive number to indicate that it is side one of the drive has the effect of supporting eight single-sided drives: 0–3 are side zero , 4–7 are side one. The side number is divided by four to give the ordinary zero or one before it is stored in Command4 as the head number.

```
*
* Setup
* sets up command buffer for reads and writes
*
* Input:
* d3.b floppy command byte
* (a0.l) pointer to drive table
* (a1.l) path descriptor
* (a2.l) device static storage
* (a3.l) pointer to port
```

```
*
* Returns:
* d4.b command size
*
01b2 48e7  Setup:   movem.l d0–d1,–(a7)
01b6 122a           move.b  V_Side(a2),d1     is it side 0
01ba 670e           beq.s   SetUp20           branch if so
01bc=0c29           cmpi.b  #2,PD_SID(a1)     can device do double sided disks?
01c2 654c           blo.s   SetUpErr          branch if not
01c4 832a           or.b    d1,Command2(a2) merge with drive #
01c8 e409           lsr.b   #2,d1             move again for side register
01ca 1541  SetUp20  move.b  d1,Command4(a2) set head number
01ce 156a           move.b  V_Track(a2),Command3(a2) set up track #

01d4=0829           btst    #PDDN_Bit,PD_DNS(a1) is device double density?
01da 6704           beq.s   SetUp60           branch if not
01dc 08c3           bset    #MF_Bit,d3        set density bit in command
01e0 102a  SetUp60  move.b  V_Sector(a2),d0   get the sector number
01e4=d029           add.b   PD_SOffs(a1),d0 add in sector offset
01e8 1540           move.b  d0,Command5(a2) set up sector #
01ec 157c           move.b  #N,Command6(a2) set up bytes per sector
01f2 156a           move.b  V_Sector(a2),Command7(a2) say last sector on track
01f8 157c           move.b  #GPL,Command8(a2) set up gap length
01fe 157c           move.b  #DTL,Command9(a2)
0204 7809           moveq   #9,d4             set command size
0206 1543           move.b  d3,Command1(a2) set command
020a 4cdf           movem.l(a7)+,d0–d1
020e 4e75           rts

           SetUpErr
0210 4cdf           movem.l(a7)+,d0–d1
0214=323c           move.w  #E$BTyp,d1
0218=003c           ori     #Carry,ccr
021c 4e75           rts
```

Restore is called from XfrSec as part of error recovery and from the `SS_Reset` setstat. It selects a drive (which sets the Command2 byte) and attempts to seek to track five. Then it uses the controller's F.Rest command to restore the head to track zero.

The seek to track five gives the head a little motion if it is already on track zero before the restore. If restore is called to help recover from an error, this motion could be important. Seeking to track five is also important on some older drives that may move the head beyond track zero. By moving the head out a few tracks before restoring it, the driver gets the head out of this hole.

```
*
* Restore Drive to Track Zero
*
* Input: a1 = Path descriptor ptr
* a3 = Controller base address
* a2 = Static Storage ptr
*
* NOTE: This routine steps in several tracks before issuing
* the restore command.
*
              Restore:
021e 612e               bsr.s     Select            select drive
0220 652a               bcs.s     Restor20          branch if error
0222 157c               move.b    #5,V_Track(a2)    seek out five tracks
0228 6152               bsr.s     SetTrk
022a 6520               bcs.s     Restor20          exit with error
022c 157c               move.b    #F.Rest,Command1(a2)
0232 422a               clr.b     Command3(a2)      looking for track 0
0236 7802               moveq     #2,d4             set # of command bytes
0238 48a7               movem.w d7,–(a7)            save transfer mode
023c 7e00               moveq     #0,d7
023e 617a               bsr.s     DoComand          issue seek command
0240 4c9f               movem.w (a7)+,d7
0244 6506               bcs.s     Restor20
0246=317c               move.w    #0,V_TRAK(a0)
024c 4e75  Restor20     rts
```

The Select routine uses the PD_DRV field from the path descriptor to set various fields that depend on the drive number:

- It sets the side to zero. This isn't strictly a drive number issue, but ….
- It sets AO to point to the drive table entry for this drive. This pointer was pre-calculated by the file manager and saved in PD_DTB. The driver just moves it to AO.
- If the drive number is different from the drive number used for the driver's last operation, Select checks the drive number against the maximum permissible drive number and returns an error if the drive number is illegal.
- The drive number is stored in Command2.

To recapitulate:

V_Side	Is set to 0
A0	Is set to PD_DTB
V_CurDrv	Is set to PD_DRV
Command2	Is set to PD_Drv

```
*
* Select Drive
*
* Set up hardware to select proper drive.
* UpDate & Return drive table pointer.
* Clear V_Side,V_Seek
*
* Input:
* (a1) = path descriptor
* (a2) = Static Storage ptr
* (a3) = Device physical address
*
* Returns:
* (a0) = pointer to current drive table
024e 157c  Select:    move.b  #0,V_Side(a2)      set side zero
0254=2069             movea.l PD_DTB(a1),a0      point to drive table

0258=1029             move.b  PD_DRV(a1),d0      Get Logical Unit Number
025c b02a             cmp.b   V_CurDrv(a2),d0    Same drive as before?
0260 670a             beq.s   Select30           branch if so
0262=b02a             cmp.b   V_NDRV(a2),d0      drive in range?
0266 640a             bhs.s   BadDrive           branch if so
0268 1540             move.b  d0,V_CurDrv(a2)    Update drive #
026c 1540  Select30   move.b  d0,Command2(a2)    Save drive #
0270 4e75             rts

0272=323c  BadDrive   move.w  #E$Unit,d1         flag bad unit
0276=003c             ori     #Carry,ccr
027a 4e75             rts
```

SetTrk compares V_Track, the target track, to V_TRAK, the current track. If V_TRAK equals V_Track, the head is already in the right place and SetTrk returns without changing anything.

If the head needs to be moved, SetTrk builds a command buffer:

- Command1 is set to F.Seek, the NEC765 op code for seeking.
- Command2 is already set to the drive number by a previous call to Select.
- Command3 is set to the target track, V_Track.

DoCommand is used to send the command to the controller.

```
*
* Step Head to New Track
*
* Input:
* (a0) = pointer to drive tables
* (a1) = path descriptor
* (a2) = Static Storage ptr
* (a3) = Device physical address
027c 102a  SetTrk:   move.b  V_Track(a2),d0
0280=b028            cmp.b   V_TRAK(a0),d0  same track?
0284 6720            beq.s   SetTrk20       branch if so
0286 157c  SetTrk10  move.b  #F.Seek,Command1(a2) set command buffer
028c 1540            move.b  d0,Command3(a2) Buffer track #
0290 7803            moveq   #3,d4          set command count
0292 48a7            movem.w d7,–(a7)       save
0296 7e00            moveq   #0,d7
0298 6120            bsr.s   DoComand       issue seek command
029a 4c9f            movem.w (a7)+,d7
029e 6506            bcs.s   SetTrk20
02a0=116a            move.b  V_Track(a2),V_TRAK(a0)
02a6 4e75  SetTrk20  rts
```

The FDC can't receive commands at arbitrary intervals. It takes time to digest a command and more time to complete the command. The Wait routine delays 12 microseconds for the FDC's registers to become valid. Then it polls the FDC's main status register at full speed, looking for the flag that indicates that the data register is ready.

Delay returns after at least 12 microseconds have passed. This routine can be called between writing to the FDC and reading the FDC's main status register.

Wait returns when the RQM bit in the FDC's main status register is on.

```
* Wait for controller ready
*
* Input:
* (a0) = pointer to drive tables
* (a1) = path descriptor
* (a2) = Static Storage ptr
* (a3) = Device physical address
*
```

```
* Returns:
* (d1.b) = status of disk controller
*
* Destroys: d1
*
* Calls: Delay
*
02a8 6108 Wait:     bsr.s    Delay          wait for valid status
02aa 122b Wait20    move.b   MSR(a3),d1     ready for command?
02ae 6afa           bpl.s    Wait20         branch if not
02b0 4e75           rts

* Delay 12 Micro Seconds for controller to give
* valid status
*
* Destroys d1
*
02b2 720a Delay     moveq    #DelayTim,d1
02b4 5301 Delay10   subq.b   #1,d1
02b6 6afc           bpl.s    Delay10
02b8 4e75           rts
```

DoComand controls the submission of the command buffer to the FDC. The high-level outline of DoComand is:

```
Wait for the FDC to become "ready."
Move all but the last byte in the command buffer into the FDC.
If this is a read
    Mask interrupts.
    Send the last byte in the command buffer.
    Disable interrupts from the FDC.
    Move data from the FDC to the data buffer.
    Unmask interrupts.
    Check for errors and return.
If this is a write
    Mask interrupts.
    Send the last byte from the command buffer.
    Disable interrupts from the FDC.
    Move data from the data buffer into the FDC.
    Unmask interrupts.
    Check for errors and return.
If this is not a read or a write
    If the command is Specify
        It came from init, don't wait for completion.
        Return.
    Mask interrupts.
```

```
Set up for interrupts.
Send the last byte from the command buffer.
Enable FDC interrupts.
Unmask interrupts.
Sleep until the interrupt handler signals.
Check for errors and return.
```

The first block in DoComand waits for the device to become ready for a command. First, it polls the DIO bit waiting for the device to be ready for commands. Then, it polls for the FDC to get out of execution mode. Finally, it polls for the FDC to indicate that none of its disks are in seek mode. If the drive door is open, or some similar problem, the driver could be stuck permanently in the polling loop. To prevent this, the loop is limited to 50 iterations. If the device isn't ready after 50 times around the polling loop, the driver gives up and declares that the device is not ready.

```
*
* Issue Transfer Commands
*
* Input:
* (a0) = pointer to drive tables
* (a1) = path descriptor
* (a2) = Static Storage pointer
* (a3) = Device physical address
* (a5) = buffer pointer
* (d4.b) = # of command bytes
* (d7.b) = transfer mode 0=IRQ 1=read 2=write
*
* Returns:
* (d1.w) = Error Code (if any)
* ccr = Carry set if error
*
* Destroys: d0,d1,d3,d4
*
* Calls: Wait, ReadRslt
*
          DoComand:
02ba 48e7           movem.l a0-a6/d7,-(a7)  savem all

* this code makes sure the controller is ready to accept commands

02be 7032           moveq  #50,d0           try fifty times
02c0 082b DoCmnd10  btst   #DIO_Bit,MSR(a3) device ready for commands?
02c6 6718           beq.s  DoCmnd40         branch if so
02c8 4a2b           tst.b  DataReg(a3)      ready byte of data
02cc 61e4           bsr.s  Delay            wait before testing again
02ce 51c8           dbra   d0,DoCmnd10      try again
```

```
02d2=323c DoCmnd20 move.w #E$NotRdy,d1   exit with error
02d6 4cdf          movem.l (a7)+,a0–a6/d7
02da=003c          ori     #Carry,ccr      set the carry
02de 4e75          rts                     exit with error

02e0 082b DoCmnd40: btst   #CB_Bit,MSR(a3) still execution mode?
02e6 66ea          bne.s   DoCmnd20        branch if so
02e8 102b          move.b  MSR(a3),d0      get controllor status
02ec 0200          andi.b  #(D0B!D1B!D2B!D3B),d0 any devices in seek mode
02f0 6718          beq.s   DoCmnd50        branch if not
02f2 177c          move.b  #F.SnsIRQ,DataReg(a3) sense irq status
02f8 61ae          bsr.s   Wait
02fa 4a2b          tst.b   DataReg(a3)     get first sense byte
02fe 61a8          bsr.s   Wait
0300 4a2b          tst.b   DataReg(a3)     get last sense byte
0304 0201          andi.b  #(D0B!D1B!D2B!D3B),d1 any devices in seek mode
0308 66d6          bne.s   DoCmnd40        branch if so
```

The device is ready. Move all but the last byte of the command buffer into it.

```
030a 49ea DoCmnd50 lea     Command1(a2),a4 point to command buffer
030e 5504          subq.b  #2,d4           adjust loop count
0310 6196 DoCmnd80 bsr.s   Wait            wait for valid status
0312 175c          move.b  (a4)+,DataReg(a3)
0316 51cc          dbra    d4,DoCmnd80     branch until one byte left
```

If this is not a data-transfer command, branch to IRQCmnd. If it is a data transfer command, prepare pointers to the data register and the data buffer and select read or write.

```
031a 618c          bsr.s   Wait            wait for valid data
031c 4a07          tst.b   d7              transfer data?
031e 6700          beq     IRQCmnd         branch if not
0322 4ded          lea     256(a5),a6      last byte to move
0326 41eb          lea     DataReg(a3),a0  point directly to data register
032a e20f          lsr.b   #1,d7           is it a read?
032c 6528          bcs.s   DoRead          branch if so
```

This block of code transfers data into the FDC for a write. Mask interrupts for speed and move the data buffer into the FDC's data register. When all the data is transferred into the FDC, touch the TermCnt register to signify the end of the write.

```
032e 40e7          move    sr,–(a7)        save IRQ status
0330=46fc          move    #Supervis+IntMask,sr mask IRQs
0334 109c          move.b  (a4)+,(a0)      move last byte
0336 422b          clr.b   IntEnabl(a3)    disable IRQs
```

```
033a 7207            moveq   #DelayTim–3,d1 wait 12 us
033c 5301  DoCmnd90 subq.b #1,d1
033e 6afc            bpl.s   DoCmnd90
0340 4a13  DoWrite   tst.b   (a3)           ready to move data
0342 6afc            bpl.s   DoWrite        branch if not
0344 0813            btst    #Busy_Bit,(a3) in execution phase?
0348 6732            beq.s   TfrDone        branch if not
034a 109d            move.b  (a5)+,(a0)     move data to controller
034c bbce            cmpa.l  a6,a5          moved last byte?
034e 66f0            bne.s   DoWrite        branch if not
0350 4a2b            tst.b   TermCnt(a3)    flag last byte written
0354 6026            bra.s   TfrDone        all done get results
```

The following block of code transfers data from the FDC to the data buffer for a read. It is almost identical to the write code above.

```
0356 40e7  DoRead    move    sr,–(a7)           save IRQ status
0358=46fc            move    #Supervis+IntMask,sr mask IRQs
035c 109c            move.b  (a4)+,(a0)         move last byte
035e 422b            clr.b   IntEnabl(a3)       disable IRQs
0362 7207            moveq   #DelayTim–3,d1 wait 12 us
0364 5301  DoRead10 subq.b  #1,d1
0366 6afc            bpl.s   DoRead10
0368 4a13  DoRead20 tst.b   (a3)               ready to move data
036a 6afc            bpl.s   DoRead20           branch if not
036c 0813            btst    #Busy_Bit,(a3)     in execution phase?
0370 670a            beq.s   TfrDone            branch if not
0372 1ad0            move.b  (a0),(a5)+         move data from controller
0374 bbce            cmpa.l  a6,a5              moved last byte?
0376 66f0            bne.s   DoRead20           branch if not
0378 4a2b            tst.b   TermCnt(a3)        flag last byte read
```

The read and write blocks of code rejoin here at TfrDone.

```
           TfrDone
037c 46df            move    (a7)+,sr           unmask irqs
037e 4cdf            movem.l(a7)+,a0–a6/d7

* fall through to read results
* Read Results
* Reads results bytes of command just executed.
*
* Input:
* (a1) = path descriptor
* (a2) = Static Storage ptr
* (a3) = Device physical address
*
* Returns:
* d1 = os9 error code
* ccr = carry set if error
*
0382 48e7  ReadRslt  movem.l d0/a0,-(a7)
0386 41ea            lea     Results(a2),a0     point to result buffer
038a 6004            bra.s   ReadRs40
038c 10eb  ReadRs10  move.b  DataReg(a3),(a0)+ move data to buffer
0390 6100  ReadRs40  bsr     Wait               wait for controller ready
0394 082b            btst    #DIO_Bit,MSR(a3) still reading data
039a 66f0            bne.s   ReadRs10           branch if so
```

The following block of code converts the result code from the FDC into an OS-9 error code or a successful return.

```
           ErrorTst
039c 102a            move.b  Results(a2),d0
03a0 0200            andi.b  #(IC!EC!NR),d0  strip all but error bits
03a4 674a            beq.s   No_Error        exit with no errors
03a6=323c            move.w  #E$NotRdy,d1    flag not ready error
03aa e300            asl.b   #1,d0           valid command?
03ac 6538            bcs.s   Error_Ex        branch if not
03ae 0800            btst    #(EC_Bit+1),d0  bad equipment?
03b2 6632            bne.s   Error_Ex        branch if so
03b4 102a            move.b  Results+1(a2),d0 get next result byte
03b8 b07c            cmp.w   #EN,d0          any errors in this reg
03bc 6732            beq.s   No_Error        branch if not
03be=323c            move.w  #E$Seek,d1
03c2 e208            lsr.b   #1,d0           seek error?
03c4 6524            bcs.s   Err_Ex1         branch if so
03c6 0800            btst    #(ND_Bit-1),d0  seek error?
03ca 661a            bne.s   Error_Ex        branch if so
03cc=323c            move.w  #E$WP,d1
03d0 e208            lsr.b   #1,d0           write protect?
03d2 6516            bcs.s   Err_Ex1         branch if so
03d4=323c            move.w  #E$DevBsy,d1    flag device busy
03d8 e608            lsr.b   #3,d0
03da=323c            move.w  #E$CRC,d1       flag crc error
03de e208            lsr.b   #1,d0           crc error?
03e0 6508            bcs.s   Err_Ex1         branch if so
```

```
03e2=323c          move.w  #E$Unit,d1       catch all error
          Error_Ex
03e6=003c          ori      #Carry,ccr      set carry
03ea 4cdf Err_Ex1  movem.l(a7)+,a0/d0
03ee 4e75          rts

          No_Error
03f0 7200          moveq   #0,d1            clear carry
03f2 4cdf          movem.l(a7)+,a0/d0
03f6 4e75          rts                      exit with no error
```

IRQCmd is used for commands that don't transfer data—seek commands and specify commands. The seek command can be particularly slow, so it is important not to tie up the processor for the duration of a seek.

This driver only sleeps during seeks, but drivers should, in general, try to sleep whenever they need to wait for an event that the device can signal with an interrupt.

The driver doesn't need to wait for results from the specify command. It comes to IRQCmd because the specify command isn't a data transfer command, but the command only sets the step rate and so forth, and it is only done at initialization time. IRQCmnd moves the specify command into the FDC and returns without even checking for a result code.

Other commands get to IRQCm10. Here the driver:

- Calls for interrupts from the FDC
- Stores the current process number (which is stored in V_BUSY) into V_WAKE
- Finishes the command by writing the last byte of the FDC command buffer into the FDC controller
- Sleeps

When the device raises an interrupt to indicate that the command has completed, the interrupt handler gets control and sends a signal to the waiting process. IRQCmnd will resume after the sleep when it gets the signal.

The interrupt, and thus the signal, could mean that the seek completed successfully. They could also mean that the seek did not work. In SenseIRQ the driver asks the FDC for status information and verifies that the seek completed at the right track.

```
*
* Issue Last Command from command buffer
* using interrupts.
*
* Input:
* (a0) = pointer to drive tables
* (a1) = path descriptor
* (a2) = Static Storage ptr
* (a3) = Device physical address
*
          IRQCmnd
03f8 121c          move.b  (a4)+,d1          get last command
03fa 4cdf          movem.l (a7)+,a0–a6/d7
03fe 0c2a          cmpi.b  #F.Specfy,Command1(a2) specify command?
0404 6608          bne.s   IRQCm10           branch if not
0406 1741          move.b  d1,DataReg(a3)    move last command
040a 7200          moveq   #0,d1             no errors
040c 4e75          rts                       exit

040e 40e7 IRQCm10  move    sr,–(a7)          save IRQ status
0410 46ea          move    V_IMask(a2),sr    mask IRQs
0414=356a          move.w  V_BUSY(a2),V_WAKE(a2) set up for interrupt
041a 1741          move.b  d1,DataReg(a3)    move last command
041e 177c          move.b  #1,IntEnabl(a3)   enable FDC irqs
0424 46df          move    (a7)+,sr          enable IRQs
0426 7000 IRQCm20  moveq   #0,d0             sleep forever
0428=4e40          os9     F$Sleep
042c=4a6a          tst.w   V_WAKE(a2)        valid wakeup?
0430 66f4          bne.s   IRQCm20           branch if not

* fall through to sense what caused the IRQ

*
* Sense Irq
*

          SenseIRQ
0432 422b          clr.b   IntEnabl(a3)      disable IRQs
0436 177c          move.b  #F.SnsIRQ,DataReg(a3) give controller command
043c 6100          bsr     Wait
0440 182b          move.b  DataReg(a3),d4
0444 0c04          cmpi.b  #Invalid,d4
0448 67e8          beq.s   SenseIRQ
044a 6100          bsr     Wait
044e 142b          move.b  DataReg(a3),d2    read last byte
0452 0804          btst    #Seek_Bit,d4      was seek complete
0456 670a          beq.s   Sens_Err          branch if not
0458 b42a          cmp.b   Command3(a2),d2 seek to right track?
045c 6604          bne.s   Sens_Err          branch if not
```

```
045e 7200               moveq   #0,d1
0460 4e75               rts

             Sens_Err
0462=323c               move.w  #E$NotRdy,d1
0466=003c               ori     #Carry,ccr
046a 4e75               rts
```

D.9 Getstat and SetStat

This driver supports two setstats and no getstats. The `SS_Reset` setstat branches to the Restore routine, and the `SS_WTrk` setstat branches to a special routine.[8]

```
**
* GetStat/PutStat

* Passed: (d0.w)=Status Code
* (a1)=Path Descriptor
* (a2)=Static Storage Address
* (a4) = Process descriptor pointer
* (a5) = Caller's register stack pointer
* (a6) = System global data storage pointer
* Returns: Depends on status code
*
046c=266a PutStat       movea.l V_PORT(a2),a3
0470=0c40               cmpi.w  #SS_WTrk,d0     is it a Write Track call?
0474 6712               beq.s   WriteTrk        branch if so
0476=0c40               cmpi.w  #SS_Reset,d0    is it a restore call?
047a 6700               beq     Restore         branch if so
047e=323c GetStat       move.w  #E$UnkSvc,d1    flag unknown service code
0482=003c               ori     #Carry,ccr      flag error
0486 4e75               rts
```

Since writing tracks bypasses all OS-9 disk security and could easily destroy the disk structure, it checks for format permission in the path descriptor. If the device descriptor didn't specify format permission, the driver won't permit the write track operation.

WriteTrk is very similar to TfrSec except that it concerns itself with sector numbers in an entirely different way from TfrSec.

WriteTrk builds the command buffer with information about the disk, the drive number, the side, the track number, and the write density. It also constructs an abreviated description of the track in the path's normal buffer. The buffer uses four bytes to describe each sector:

[8]The writetrack setstat is normally used to format disks.

- Cylinder number
- Head number
- Record number
- Bytes per sector

The record number is taken from an interleave table supplied by the caller. The other values are from the path descriptor or calculated by the driver.

At four bytes per sector, a standard 256-byte buffer can describe a 64-sector track. If the controller requires an actual track image, the driver must either allocate a large buffer for the track image and build the image in the new buffer (and free it after it is written), or trust the calling program to construct a correct track image and use the track buffer pointed to by the caller's register A0.

```
*
* WriteTrk
*
* Write track buffer to disk
**
                WriteTrk
0488=0829          btst    #FmtDis_B,PD_Cntl+1(a1) enable for formatting
048e 670a          beq.s   WrtTrk10         branch if so
0490=323c          move.w  #E$Format,d1     flag bad mode
0494=003c          ori     #Carry,ccr       exit with flag
0498 4e75          rts
049a=266a WrtTrk10 movea.l V_PORT(a2),a3
049e 177c          move.b  #1,MotorCtl(a3)  turn on drive motor
04a4 6100          bsr     Select           select proper drive
04a8 6500          bcs     WrtTrkEx         exit with error
04ac=2869          movea.l PD_RGS(a1),a4    get register pointer
04b0=156c          move.b  R$d2+3(a4),V_Track(a2) save track # for seek
04b6 6100          bsr     SetTrk           seek to track
04ba 6500          bcs     WrtTrkEx
04be 157c          move.b  #F.WrtTrk+DDensity,Command1(a2) select command
04c4 157c          move.b  #N,Command3(a2) Set up # bytes per sector
04ca=1569          move.b  PD_SCT+1(a1),Command4(a2) get sectors/track
04d0=362c          move.w  R$d3+2(a4),d3    get format byte
04d4 103c          move.b  #GPL5DD,d0       default to 5" drive
04d8=0829          btst    #Size_Bit,PD_TYP(a1) is it 5"
04de 6612          bne.s   WrtTrk15         branch if not
04e0 0803          btst    #Dens_Bit,d3     is it double density?
04e4 6620          bne.s   WrtTrk25         branch if so
04e6 103c          move.b  #GPL5SD,d0       set up 5" single density
04ea 08aa          bclr    #MF_Bit,Command1(a2) clear double density bit
04f0 6014          bra.s   WrtTrk25
```

```
04f2 103c  WrtTrk15 move.b  #GPL8DD,d0     default to double density
04f6 0803           btst    #Dens_Bit,d3   is it double density?
04fa 660a           bne.s   WrtTrk25       branch if so
04fc 103c           move.b  #GPL8SD,d0     set gap to single density
0500 08aa           bclr    #MF_Bit,Command1(a2) clear double density bit

0506 1540 WrtTrk25  move.b  d0,Command5(a2) setup gap length
050a 157c           move.b  #Filler,Command6(a2) set filler byte

* Figure side

0510=1143           move.b  d3,DD_FMT(a0)
0514 0803           btst    #Side_Bit,d3   is it side 0?
0518 670c           beq.s   WrtTrk30       branch if so
051a 157c           move.b  #1,V_Side(a2)  set to side 1
0520 08ea           bset    #2,Command2(a2) set to head 1
0526=102c WrtTrk30  move.b  R$d2+3(a4),d0  get track #
052a 122a           move.b  V_Side(a2),d1  get side #
052e 7601           moveq   #N,d3          get # bytes/sector
0530=3829           move.w  PD_SCT(a1),d4  get # of sectors/track
0534 5344           subq.w  #1,d4          adjust for loop count
0536 4bea           lea     V_BUF(a2),a5   build track buffer
053a=2c6c           movea.l R$a1(a4),a6    get interleave table pointer

053e 1ac0  WrtTrk40 move.b  d0,(a5)+       set cylinder #
0540 1ac1           move.b  d1,(a5)+       set head #
0542 1ade           move.b  (a6)+,(a5)+    get record #
0544 1ac3           move.b  d3,(a5)+       set # of bytes/sector
0546 51cc           dbra    d4,WrtTrk40

054a 7806           moveq   #6,d4          get # of command bytes
054c 7e02           moveq   #2,d7          set transfer mode to write
054e 4bea           lea     V_BUF(a2),a5   point to track buffer
0552 6100           bsr     DoComand       execute the command
0556 650a           bcs.s   WTrkEr10
0558=266a           movea.l V_PORT(a2),a3
055c 422b           clr.b   MotorCtl(a3)   turn off drive motor
0560 4e75  WrtTrkEx rts

0562=266a WTrkEr10  movea.l V_PORT(a2),a3
0566 422b           clr.b   MotorCtl(a3)   turn off drive motor
056a=003c           ori     #Carry,ccr
056e 4e75           rts
```

D.10 Terminate

The terminate routine is called by IOMan when the device is detached. It should reverse the effects of the init routine (except that it doesn't need to de-initialize static storage variables).

For this driver, the termination routine only has to disable interrupts from the device and remove it from the interupt polling table.

It is not likely that interrupts from the device would be enabled, but the termination routine should be extremely careful about interrupts. If OS-9 can't find an interrupt handler that will take responsibility for an interrupt, it will ignore that interrupt in the future. This is a desperate move.

If the driver may have outstanding operations, the termination routine should abort the operations gracefully or wait for them to terminate before returning. This would be an issue if, for instance, the driver maintained a write-behind cache. Recent writes might be stored in the driver's buffers but not yet written to disk. The termination routine would be obliged to flush the write cache to the disk before returning. If the driver allowed itself to terminate without flushing its buffers, the data in the buffered writes would be lost.

```
*
* Terminate use of device
*
* Passed:
* (a1) = device descriptor
* (a2) = device static storage
* (a6) = System global data storage pointer
*
* Returns: Nothing
*
            Term
0570=266a          movea.l V_PORT(a2),a3  get port address
0574 177c          move.b  #0,IntEnabl(a3)  disable interrupts on device
057a=1029          move.b  M$Vector(a1),d0 get vector #
057e 91c8          suba.l  a0,a0          take device off table
0580=4e40          os9     F$IRQ
0584 4e75          rts
```

D.11 Interrupt Service Routine

This interrupt handler was connected to the OS-9 polling table by the initialization routine. The interrupt service routine is called with the device's interrupt masked each time an interrupt with its vector is raised.[9]

Any number of devices can share a common hardware interrupt priority and interrupt vector. The interrupt handler's first task is to query the device and find out whether this interrupt belongs to it.

Technically, a driver can't determine whether its device actually raised the interrupt, but it doesn't matter. If another device with the same interrupt vector raised the interrupt and this device completed a command and tried to raise the interrupt a moment later, two device drivers would be ready to claim the interrupt. The driver earlier in the polling table would claim the interrupt and deal with its device; the device would respond by dropping the interrupt. When the IRQ routine returned to the kernel and the interrupt was unmasked, the other interrupt would still be asserted, this time by the other device, and the drivers would get another chance.

Action	**Interrupt mask**	**Device 1**	**Device 2**
Devices request service	0	Int	Int
Processor responds	mask	Int	Int
Driver 1 called	mask	Int	Int
Driver 1 completes	mask		Int
Kernel clears mask			Int
Process responds	mask		Int
Driver 1 called	mask		Int
Driver 1 isn't interested	mask		Int
Driver 2 called	mask		Int
Driver 2 returns	mask		
Kernel clears mask			

Theoretically, if many drivers shared a common interrupt/vector, a driver at the back of the queue might never be served. Practically, interrupt handlers are fast enough that it would take an astonishing burst of interrupts to keep the interrupt asserted for any length of time.

This interrupt handler considers three cases:

1. The driver is waiting for command completion. In this case the handler sends a wakeup signal to the sleeping process.

2. The driver is not waiting and the FDC is not ready for a command. The handler takes no action in this case.

3. The driver is not waiting and the FDC is ready for a command. The handler gives the FDC a command to sense interrupt status and reads the FDC's data register twice to throw out the result of the command.

[9]This driver assumes that the interrupt is intended for it. It must have an interrupt vector to itself.

```
*
* Interrupt Service routine
*
* Handles irqs from Seek,Restore & NotReady
*
* Passed :
* (a2) static storage pointer
* (a3) pointer to device
* (a6) system global static storage
*
* Returns :
* carry set if device didn't generate irq
**
              IRQSrvc
0586 422b              clr.b   IntEnabl(a3)     disable IRQs from controller
058a=302a              move.w  V_WAKE(a2),d0 was driver waiting?
058e 6620              bne.s   IRQSr20          branch if so
0590 082b              btst    #DIO_Bit,MSR(a3) Ready for command
0596 6622              bne.s   IRQExit          branch if not
0598 177c              move.b  #F.SnsIRQ,DataReg(a3)
059e 6100              bsr     Delay            wait 12 us
05a2 4a2b              tst.b   DataReg(a3)      read first byte
05a6 6100              bsr     Delay            wait 12 more us
05aa 4a2b              tst.b   DataReg(a3)      read second byte
05ae 600a              bra.s   IRQExit
05b0=426a IRQSr20      clr.w   V_WAKE(a2)       flag IRQ occured
05b4=7200              moveq   #S$Wake,d1       get wake up signal
05b6=4e40              os9     F$Send           send driver signal
05ba 7200 IRQExit      moveq   #0,d1
05bc 4e75              rts
000005be               ends
```

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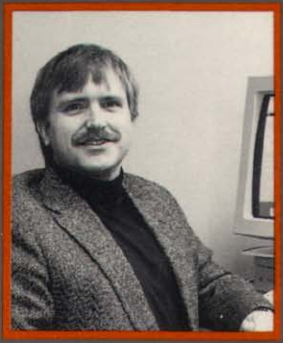
ABOUT THE AUTHOR



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